Municipality of Anchorage Natural Resources (Gravel) Extraction Management Plan

report #1
Inventory and Evaluation

December 1982

JohnsonBraund Design Group - S&S Engineers

MUNICIPALITY OF ANCHORAGE NATURAL RESOURCES (GRAVEL) EXTRACTION MANAGEMENT PLAN

REPORT #1

INVENTORY AND EVALUATION

The preparation of this report was financed in part through a Coastal Zone Management program grant from the U.S. Department of Commerce under the provisions of Section 306 of the Coastal Zone Management Act of 1972, as amended, and the Division of Community Planning, Department of Community and Regional Affairs of the State of Alaska.

Final Report

December 1982

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SUMMARY

The purpose of this report is to:

1. inventory and evaluate all known and potential gravel extraction sites within the Municipality of Anchorage and prepare an engineering estimate of supply vs. demand from 1983 to the year 2000;

2. prepare a restoration and comprehensive redevelopment plan for the Sand Lake extraction sites; and

3. prepare a Developers Manual including a requirement for a Plan of Mining Operations which is to be filed on all extraction sites -- both existing and proposed.

The above three tasks are presented in three volumes titled as follows:

Report #1 - Inventory and Evaluation
Report #2 - Sand Lake Area Comprehensive Development Plan
Developers Requirements for Natural Resource Extraction

Population projections from 1983 to 2000 furnished by the Municipality Planning Department formed the basis for the sand and gravel demand projections. Total demand of sand and gravel for housing development, commercial and industrial construction, public projects (streets, sewer and water extensions, etc.) and maintenance requirements is estimated to be 42,386,000 cubic yards between 1983 and the year 2000.

Sand and gravel supplies are estimated based upon the reserves of material contained in the existing and proposed extraction sites. Based upon many variables, the total supply available, including importation via the Alaska Railroad from the Matanuska-Susitna Valley, is projected to be 30,000,000 cubic yards between 1983 and the year 2000.

This report presents two options for considering sand and gravel supplies. Option 1 assumes all available supplies are used to their utmost and that two new reserve areas are brought into production to meet the projected demand. Option 2 assumes the loss of

production of Sand Lake and that no new areas of production are developed. These two options are presented as they relate to the supply meeting the projected demand. A deficit in the supply of between 434,000 cubic yards and 1,662,000 cubic yards is projected in 1984 depending upon whether Option 1 or Option 2 is assumed. Deficits of sand and gravel are projected to occur through 1986 (and beyond), causing a pent-up demand unless either development of new sources occurs or radical new methods of construction are adopted by both the public and private sectors which will significantly reduce consumption.

Three major potential sand and gravel reserve areas are estimated to exist: 1) that area of Glacier Creek lying westerly of the Girdwood Airport; 2) the Eklutna River Floodplain; and 3) the off-shore area of Cook Inlet in the vicinity of Pt. Woronzof. All three areas will require additional studies to determine if they are economical to develop and to determine if they contain adequate reserve volumes which will allow future mining activities.

Gravel saving techniques are discussed with the emphasis for implementation of new ideas being placed on street and utility construction since this is a major demand area.

Report #1 contains an environmental analysis of the existing extraction operations and concludes the existing mining activities do not constitute a major action significantly affecting the environment. Specific recommendations are made for the safety and aesthetic considerations of each operation which should be implemented.

I. INTRODUCTION

A. AUTHORIZATION

The preparation of this study was authorized by the Municipality of Anchorage Assembly on April 21, 1982.

The title of this study is "MUNICIPALITY OF ANCHORAGE NATURAL RESOURCES (GRAVEL) EXTRACTION MANAGEMENT PLAN", which is comprised of three separate reports:

Report #1 - Inventory and Evaluation
Report #2 - Sand Lake Area Comprehensive Development Plan
Developers Requirements for Natural Resource Extraction

This is a copy of Report #1 - Inventory and Evaluation.

This document presents an inventory and evaluation of existing and proposed sources, recommendations and policy guidelines for the management of the sand and gravel natural resource within the Municipality of Anchorage.

This report was prepared by Johnson Braund Design Group, P.S., Inc., and S & S Engineers, Inc. as a joint venture under contract with the Municipality of Anchorage, Planning Department.

B. PURPOSE OF THE STUDY

Past growth in the Municipality of Anchorage has generally been concentrated in those areas possessing surface and subsurface soil conditions suitable for conventional foundations. Areas having unsuitable soils, marginal soils or other environmentally sensitive features, have for the most part, been passed over.

Marginal soils generally have a peat overburden underlain by a soils composition which is suitable for support of structures. Normal construction practices require the excavation of the peat overburden and backfilling of the excavation with non-frost-susceptible sand

and/or gravel in order to stabilize the ground for structural support. Detailed specifications for varied soils conditions and structural types have been developed by the engineering profession over years of experience.

Growth in the Municipality of Anchorage can be expected to continue. Future development will be forced to occur on remaining sites with marginal soils. It can therefore be anticipated that demand for sand and gravel resources will be increasing in future years. The increasing demand for these resources will rapidly deplete the remaining available supply. This will tend to increase the value of these resources, potentially making extended operations of existing extraction pits advisable and increasing the viability of opening new extraction sites. At the same time, sand and gravel extraction produces a number of environmental impacts. Severe modification to existing surface features, traffic, noise, dust, storm drainage, groundwater, and numerous other impacts often have a direct effect on the adjacent communities. By imposing limitations on operations designed so as to reduce the above negative impacts it is possible, in our opinion, to allow existing operations to continue.

In the very near future, it will become the Municipality's responsibility to reconcile the public need for sand and gravel resources, together with the associated economic benefits, against the adverse environmental impacts resulting from new or continued extraction operations. In order to assist the Municipality with management of these issues, the objective of this study is as follows:

1. inventory known and potential extraction sites
2. identify operations induced environmental impact and recommend mitigative solutions
3. forecast future demand
4. quantify sand and gravel supplies
5. recommend a management plan
6. recommend a comprehensive development plan for the Sand Lake area.
7. establish the criteria for:
    a. continued operations of existing extraction sites
    b. restoration of sites not in production
    c. future extraction operations

The scope of this study has been limited to the Anchorage Municipal limits (see map, Figure I.1) with the additional consideration of sand and gravel supplies which are imported from outside Municipal limits.

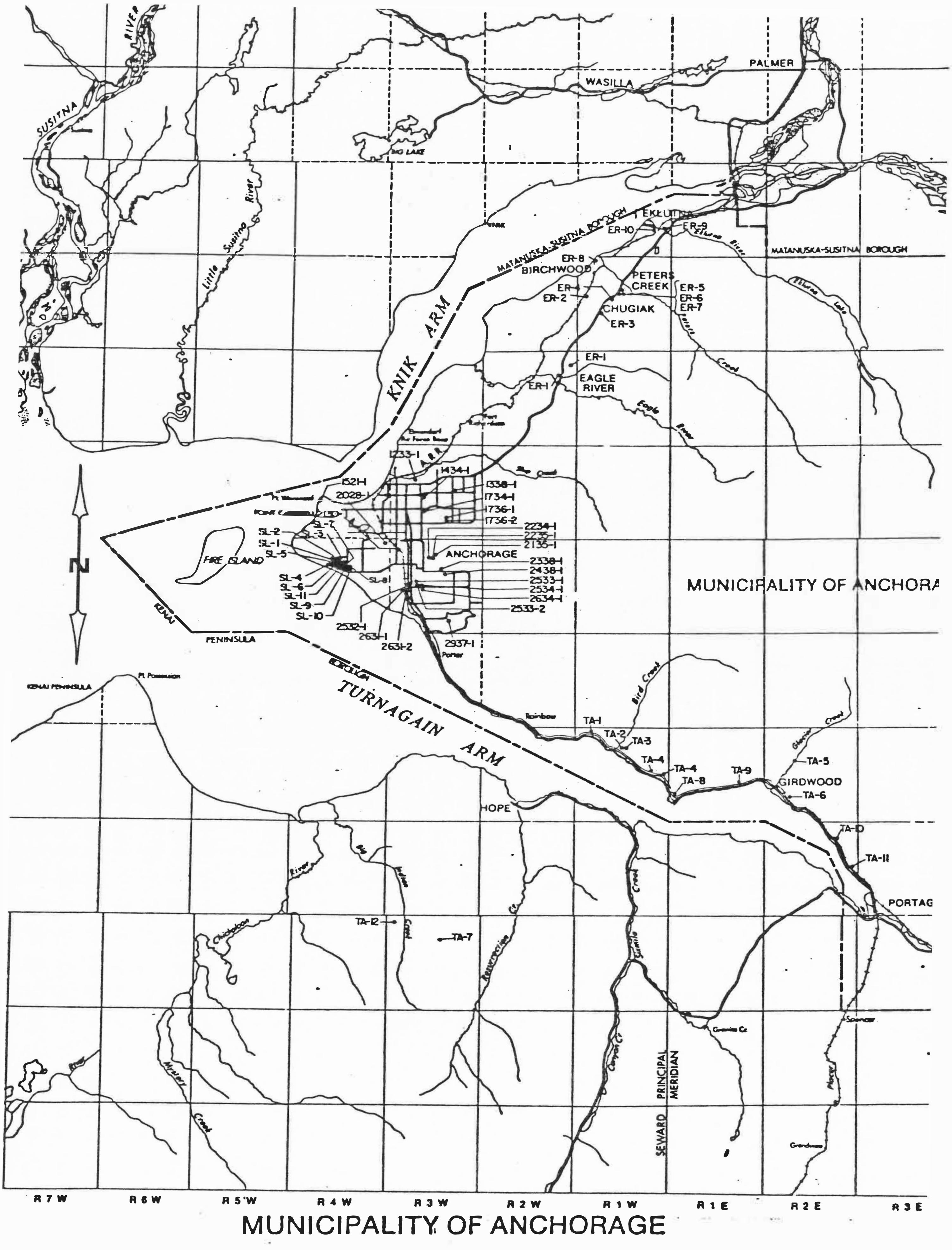
C. PREVIOUS PHASES OF THE STUDY

As the study has progressed, three separate reports were submitted to the Planning Staff for review and comment. Comments received have been incorporated into this document.

In July 1982, an Interim Report was submitted for review. This report dealt primarily with the inventory of existing and potential natural resource extraction sites, including impact-benefit assessment of all sites. The intent of the Interim Report was to present data resulting from the field studies conducted for the purpose of identifying existing, abandoned, and potential sources of sand and gravel, in order to provide a basis for later analysis.

Task Memorandum #1 was submitted in March 1982, containing the processed field inventory information, classification of impacts and benefits from mining activities, and formulation of mitigation measures. Three area-wide assessment matrices were compiled in this report, presenting the results of the field inventory program in the three geographic areas of Turnagain Arm, Anchorage Bowl, and Eagle River-Eklutna. Preliminary hydraulic recharge analyses conducted in Glacier Creek and Eklutna River were also presented in this report.

Task Memorandum #2, submitted on September 2, 1982, contained the preliminary projected resource demand values, projected source yields, development growth rates, integrated optimum production levels and a draft of the Sand Lake Area Comprehensive Development Plan.



MUNICIPALITY OF ANCHORAGE

D. PREVIOUS STUDIES

Nine previous studies have been particularly useful in the preparation of this report.

1. Future Land use Alternatives of Sand Lake Gravel Pits by: The Greater Anchorage Area Planning Borough; September 1975.

2. Municipality of Anchorage 208 Study Soil Erosion and Sediment Control for Anchorage; December 1978

3. Eagle River-Chugiak-Eklutna Comprehensive Plan by: The Municipality of Anchorage; September 1979

4. Turnagain Arm Comprehensive Plan by: The Municipality of Anchorage; December 1979

5. Sand Lake Drainage and Water Quality Management Study by: Quadra Engineering, Inc.; August 1981.

6. Anchorage Wetlands Management Plan by: The Municipality of Anchorage, Physical Planning Department; October 1981

7. Anchorage Bowl Comprehensive Development Plan by: The Municipality of Anchorage Planning Department; March 1982

8. Anchorage Coastal Zone Management Resource Atlases

9. Metropolitan Anchorage Urban Studies

The 1975 study of alternative uses to the Sand Lake gravel pits discusses in detail the reasoning behind the increased use of sand and gravel in the Anchorage area. It was recognized in 1975 that a) there was to be an increasing need for sand and gravel supplies; and b) that the local area (i.e., the Anchorage Bowl) was depleting the available sand and gravel supplies rapidly.

"The sharp increase in gravel demand has been accompanied (by) a sharp decrease in readily available supplies of quality gravel that can be obtained locally. In short, Anchorage is rapidly running out of gravel to meet its demands and will soon have to look beyond its boundaries to obtain adequate supplies. Estimates by the State Department of Highways, U.S. Geological Survey, and U.S. Corps of Engineers show that most of the existing pits in the Anchorage area are nearly exhausted and will be able to supply only a fraction of the need within the next decade."

E. ACKNOWLEDGEMENTS

Grateful appreciation is expressed to those who have participated in the development of this report. Particular thanks should go to the Municipality of Anchorage Physical Planning staff including Bruce Phelps, Tony Burns and Hadley Jenner. Also assisting in the review of all submissions was Joe Stimson of Zoning and Platting. Their concise, timely responses, coordination and assistance are hereby acknowledged.

F. RECOMMENDATIONS

This section presents our recommendations on the management, continued operations and new operations of the natural resource extraction industry within the Municipality.

1. Investigate the potential of TA-5, Glacier Creek, and ER-9, Eklutna River floodplain as a major aggregate supply source. Include in the investigation:

   a. recharge capability of the stream beds
   b. compatibility with Anchorage Wetlands and Water Quality Management Plans

2. Investigate the potential of the off-shore area of Cook Inlet in the vicinity of Pt. Woronzof as a major aggregate supply source.

3. Require each mining operation in production after December 31, 1982, to file a plan of mining operations as specified in the Developers Requirements for Natural Resource Extraction.

4. Require each proposed mining and/or extraction operation to file, as partial

fulfillment of the permit process, the Developers Requirements for Natural Resource Extraction.

5. Request written statements from all governmental agencies on the use and amortization of the natural resource extraction sites under their jurisdiction. Request restoration plans, production quantities and timetables for implementation.

6. Update on a yearly basis, the Supply and Demand projections in this report as they pertain to the production quantities of aggregate.

7. Enforce restoration plans by implementing the recommended bonding procedures outlined in the Developers Requirements for Natural Resource Extraction for all extraction sites operating after December 31, 1982.

8. Establish a committee which will oversee the experimentation suggestions given in this report which are intended to reduce the demand for sand and gravel.

9. Refer to Report #2 for Sand Lake area recommendations.

II. SAND AND GRAVEL EXTRACTION INVENTORY

A. EXISTING OPERATIONS

Introduction

This section contains information gathered during the course of this study relating to the existing natural resource locations. As stated previously, the study area was the Municipality of Anchorage. Within that study area, 65 sites were examined in four general geographic areas. These areas are Anchorage Bowl, Turnagain Arm, Eagle River/Eklutna and Sand Lake. Please refer to Figure I.1 for the locations and designations of the sites within the study area.

Up to the present time, there have been no records of sand and gravel consumption available in the Anchorage area. Existing gravel pit production information is unreliable when obtainable. Due to the unavailability of records for either demand or supply, there is no feasible method by which to establish a base year. Information and data was developed using logical engineering assumptions, knowledge based upon consumption for typical projects and conversations with developers, other engineers and pit operators.

Maps are included for each site. Included on each map are descriptions and remarks pertaining to particular pits. Prior to the Location Maps is a written summary of each geographical area followed by a tabular summary of each particular pit within the area.

Anchorage Bowl

The supply of gravel in the Anchorage Bowl area is diminishing, while the demand for this resource due to development pressures continues. In the past, natural resource extraction sites throughout this area have provided the types of sand and gravel necessary for construction, maintenance, and manufacturing of commercial products. Development has taken place in areas of once-potential gravel sources thereby eliminating some future extraction sites. This, coupled with limitations on gravel extraction operations within the Municipality, have made it difficult to replace the active pits now nearing exhaustion. Consequently, areas to the north, such as Eagle River, Chugiak, Eklutna and Palmer, have become a major source for better quality gravel. As the distance between the point of supply and the point of demand increases, so does the cost of any development requiring large quantities of sand and gravel.

Inactive pits within the Anchorage Bowl were investigated for possible future gravel and sand supplies, as well as for environmental conditions requiring mitigation. Many former sites have been redeveloped or are soon to be redeveloped. Others should not be re-opened for reasons of aesthetics, lack of transportation facilities, or the creation of a public hazard. Additionally, there is simply very little material left worth mining from these inactive pits. For the reasons outlined above, no new potential sites were identified in the Anchorage Bowl area with the exception of SL-11. This potential 10-acre site has been proposed as an extraction site by Alice Tallman. Request for removal of 160,000 to 260,000 cubic yards of gravel has been made to the Planning and Zoning Commission. This case has been neither approved nor denied and is discussed further in the Sand Lake Master Plan, Section IV.

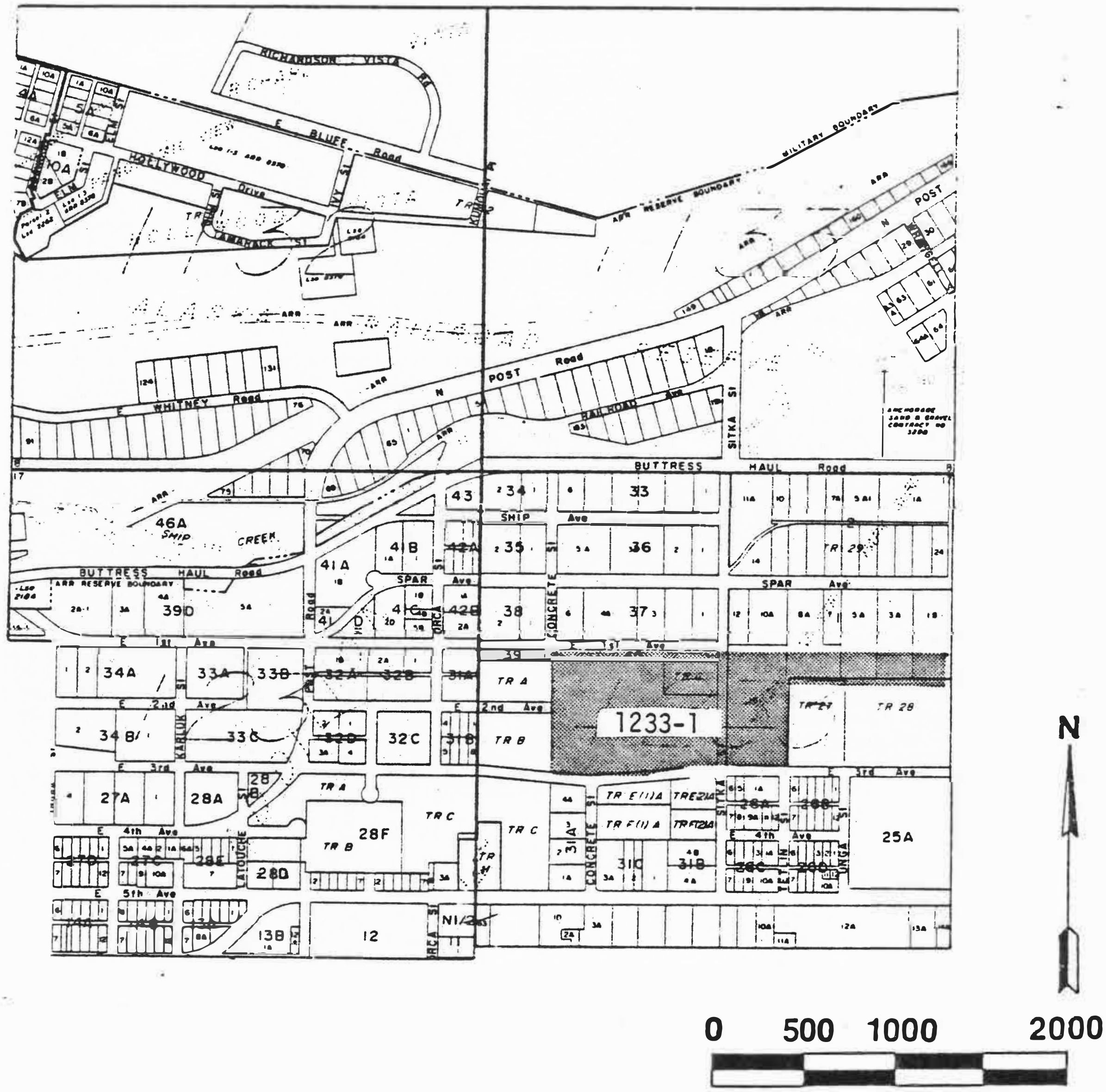
Site #2018-1, Location Map No. 10, is 120 acres lying at the west end of the east-west runway at the Anchorage International Airport. The property is owned by the State of Alaska and is used by the Alaska Department of Transportation (ADOT) as a source of sand and gravel for ADOT projects. At the present time, the site is active and based upon the memorandum in Appendix C, ADOT intends to extract approximately 1,500,000 cubic yards through 1987. If these lands are returned to the Municipality (which is currently under discussion), and this source is removed as a source of supply for ADOT requirments, then additional demands will be placed upon other existing sources. It can be expected that ADOT will require contractors on State highway projects to supply sand and gravel as a part of their proposals in order to conserve the available quantities at Site #2018-1. For purposes of this report, it has been assumed that ADOT will supply the needed quantities, as required, from sites which they own or control. This site lies within a designated wetlands area as shown on Figure 2-2, page 2-4 of the Anchorage Wetlands Management Plan (AWMP) and is classified as Preservation Land on Figure 6-4 of AWMP. Conflicts between the goals of the Municipality and the needs of ADOT should be reconciled prior to further expansion.

Existing extraction sites in the Anchorage Bowl area are summarized in Table II.1, Summary of Anchorage Bowl. Location maps for each pit follow directly after Table II.1. These maps include a brief description of the pit and general remarks. For a complete assessment of impacts and benefits, please refer to the Anchorage Bowl Area Assessment Matrices in Appendix J.

TABLE II.1 - SUMMARY OF ANCHORAGE BOWL

PIT NO.	APPROX. LOCATION	SIZE	STATUS	REMARKS
1233-1	AS&G (lst & Orca) Gravel Pit and Concrete Ready Mix Plant	25 acres	Active	53,000 c.y. gravel remaining; Removal pending Utility Relocations Processed Aggregate Trucked from Klatt Road Plant
1521-1	Pt. Woronzof	20 acres	Dormant	Erosion & Solifluction
2028-1	Central Paving Products Plant	N/A	Active	Gravel Hauled by Train from Matanuska Valley; Train Capacity - 6,400 tons/day (3830 cy/day)
2130-1	Alagco Plant	N/A	Active	Gravel Hauled by Train from Matanuska Valley; Train Capacity - 4,500 tons/day (2700 cy/day)
2135-1	N. of Lore Road, Btwn. Abbott Loop Road & Spruce St.	10 acres	Dormant	Being Filled; For Sale
2234-1	S. of Lore Road, W. of Spruce St.	12 acres	Dormant	Minor Erosion; Minor Dumping
2235-1	S. of Lore Road, E. of Spruce St.	5 acres	Dormant	Minor Erosion, Minor Dumping
2532-1	N. of O'Malley; Btwn. Old & New Seward Hwys.	20 acres	Dormant	Minor Dumping
2533-1	W. of Lake Otis; Btwn. O'Malley & Abbott	40 acres	To Be Devel.	Extensive Dumping
2533-2	NW corner of Lake Otis & O'Malley	10 acres	No Future Plans	Minor Erosion
2534-1	NE Corner of Lake Otis & O'Malley	15 acres	Restored	Part of "Sec. 16" Public Lands/Equestrian Trails
2631-1	AS&G (Klatt Road)	N/A	Active	Gravel Hauled by Train from Matanuska Valley
2631-2	W. of Old Seward; E. of Railroad, at O'Malley	20 acres	Dormant	Eyesore; Minor Dumping
2634-1	Pioneer Sand & Gravel	80 acres		1,500,000 to 2,000,000 c.y. in reserves

Anchorage Natural Resources Extraction Study Anchorage Bowl Location Map No. 1



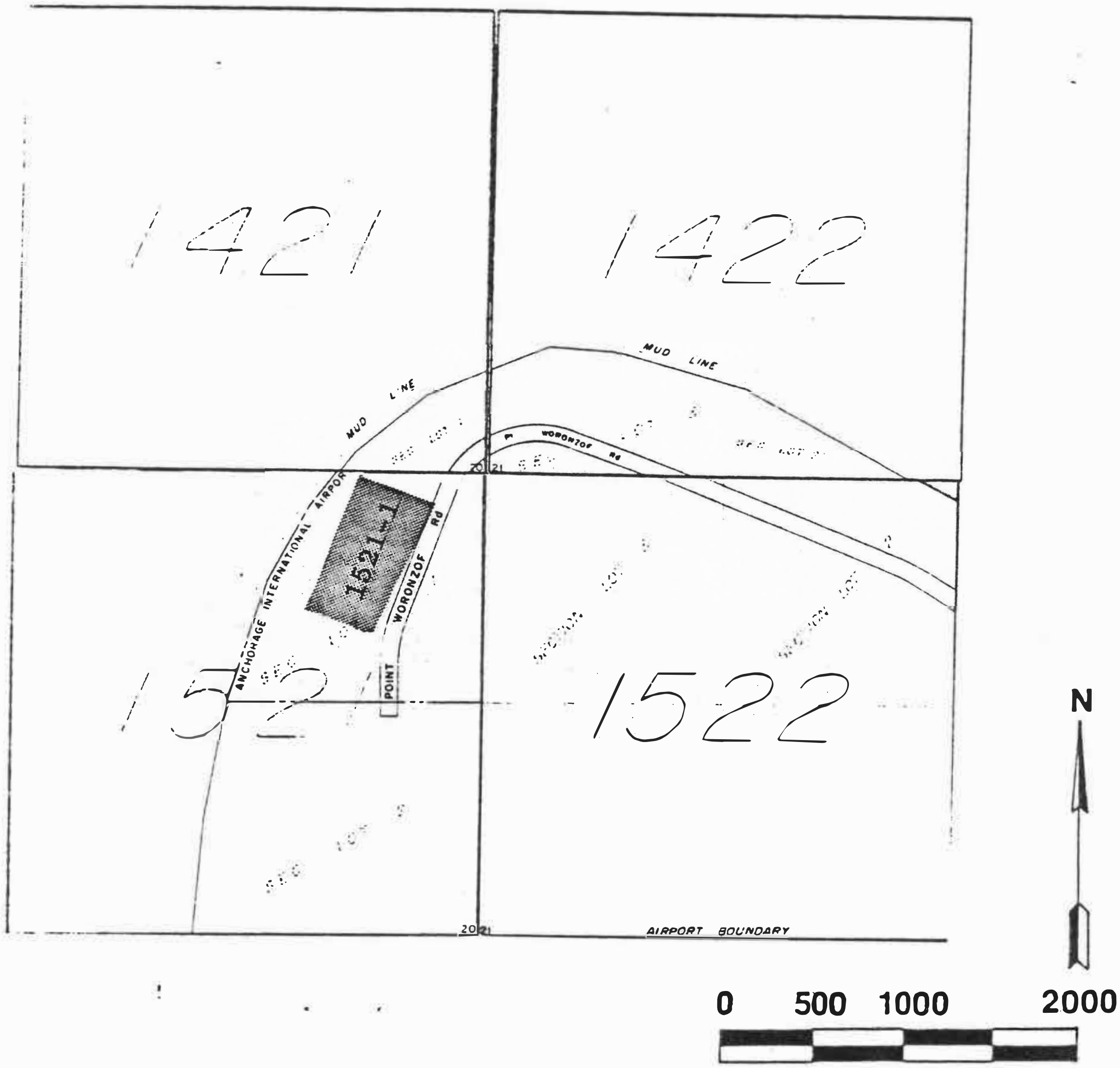
0 500 1000 2000

Scale 1"=1000'

T 13N R 3W Sec 17 Grids 1233

Pit No.	Description	Size	Status	Remarks
1233-1	AS&G (1st and Orca) Gravel Pit and Concrete Ready Mix Plant	25 Acres	Active	Pit has 40,000 cu. yds. in reserves -- to be depleted in '82 or '83. Processed aggregate for Ready Mix Plant trucked from Klatt Road Plant.

Anchorage Natural Resources Extraction Study Anchorage Bowl Location Map No. 2



T 13N R 4W Sec 20 Grids 1521

Pit No.	Description	Size	Status	Remarks
1521-1	Pt. Woronzof	20 Acres	Dormant	Erosion and Steep slopes

Anchorage Natural Resources
Extraction Study
Anchorage Bowl
Location Map No. 3

N

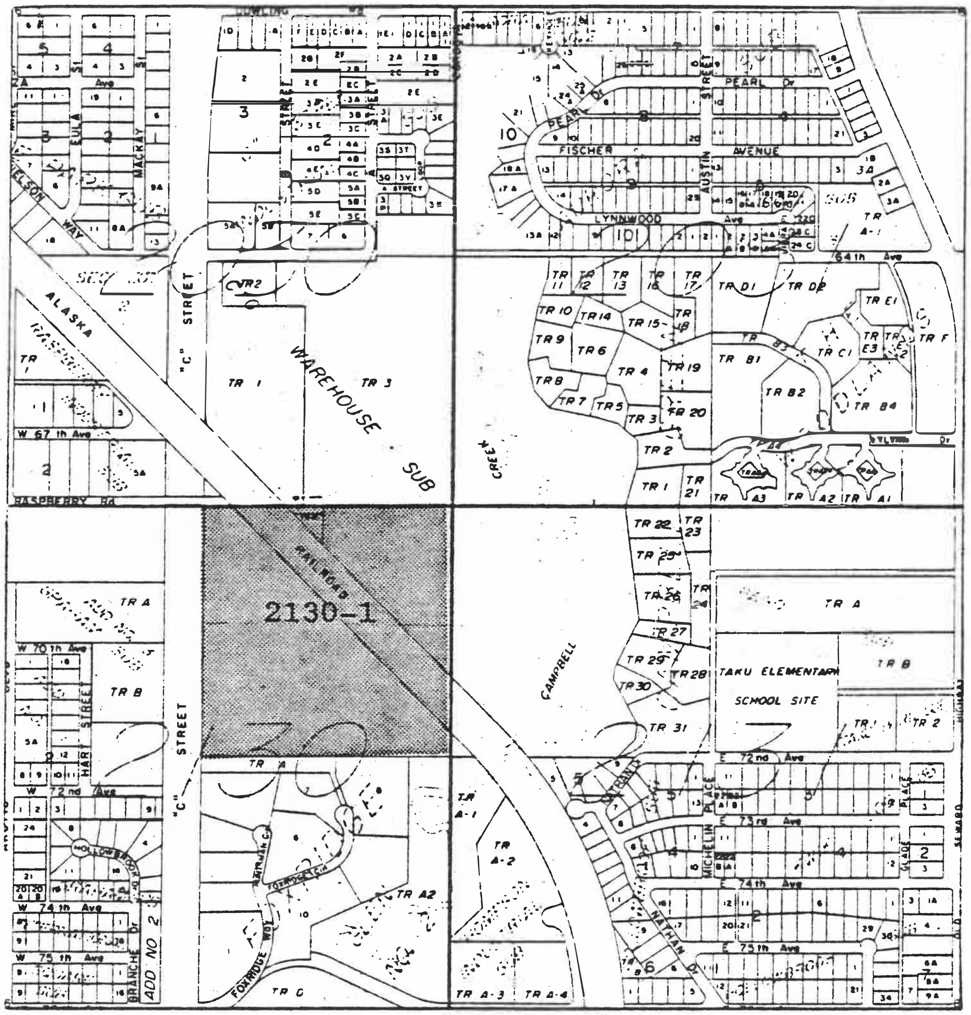
0 500 1000 2000

Scale 1"= 1000'

T 12N R 4W Sec 1 Grids 2028, 2029

Pit No.	Description	Size	Status	Remarks
2028-1	Central Paving Products	40 Acres	Active	Gravel brought by train from Matanuska Valley. Max. capacity of train = 6,400 tons/day (3,830 cy/day)

Anchorage Natural Resources
Extraction Study
Anchorage Bowl
Location Map No. 4



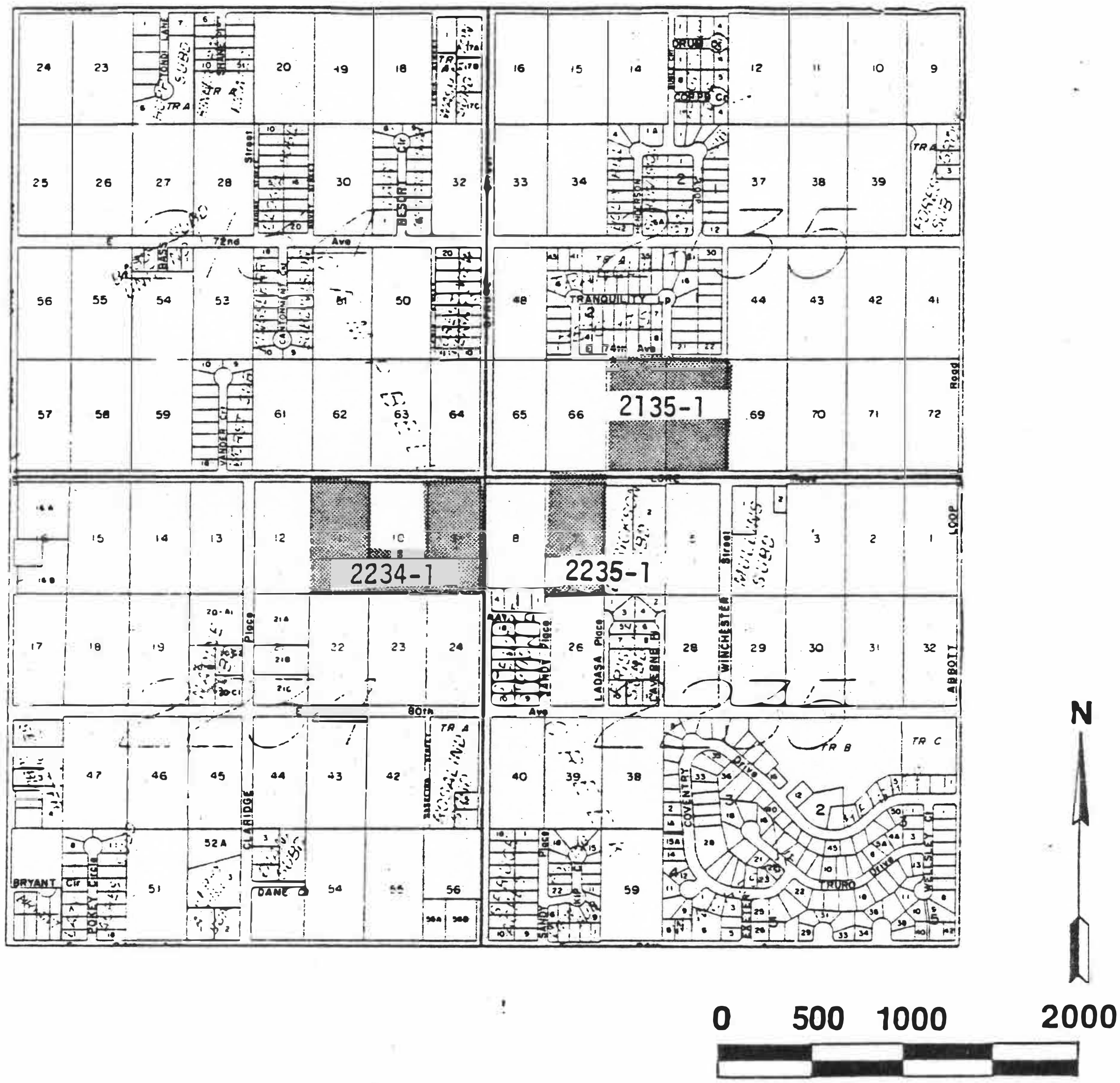
0 500 1000 2000

Scale 1"=1000'

T 12N R 3W Sec 6 Grids 2130

Pit No.	Description	Size	Status	Remarks
2130-1	Alagco Plant	40 Acres	Active	Gravel brought by train from Matanuska Valley. Max. capacity of train - 4,500 tons/day (2,700 cy/day)

Anchorage Natural Resources
Extraction Study
Anchorage Bowl
Location Map No. 5

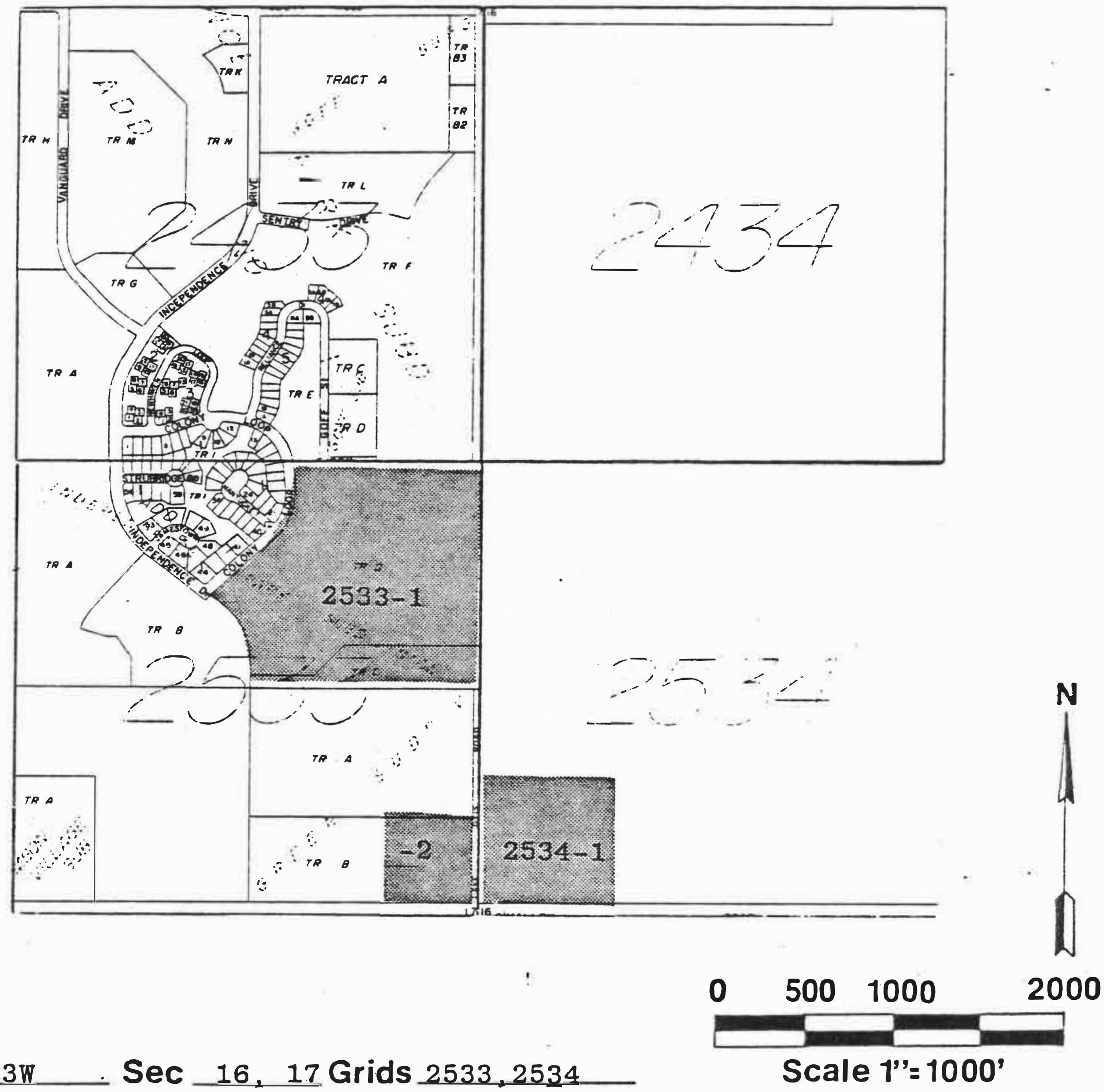


Scale 1"=1000'

T 12N R 3W Sec 4, 9 Grids 2135, 2234, 2235

Pit No.	Description	Size	Status	Remarks
2135-1	N. Lore Road, W. of Winchester St.	10 Acres	Expired	Being filled; for sale
2234-1	S. of Lore Road W. of Spruce St.	12 Acres	Dormant	Minor erosion, minor dumping
2235-1	S. of Lore Road E. of Spruce St.	5 Acres	Dormant	Minor erosion, minor dumping

Anchorage Natural Resources Extraction Study Anchorage Bowl Location Map No. 6



T 12N R 3W Sec 16, 17 Grids 2533, 2534

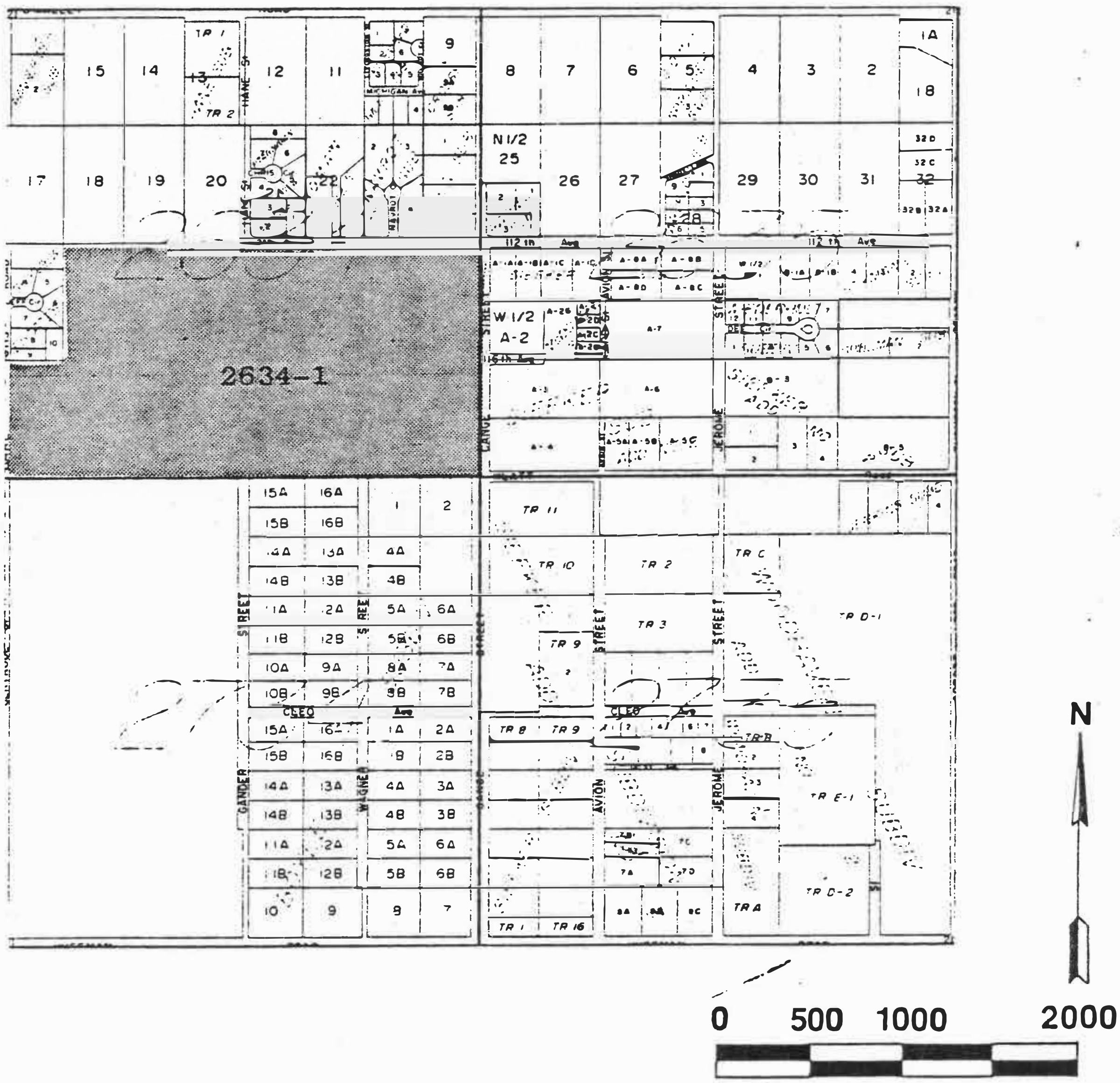
Pit No.	Description	Size	Status	Remarks
2533-1	W. of Lake Otis, btwn O'Malley & Abbott	40 Acres	To Be Developed	Extensive Dumping
2533-2	NW corner of Lake Otis & O'Malley	10 Acres	Expired	Minor Erosion
2534-1	NE corner of Lake Otis & O'Malley	15 Acres	Restored	Part of "Sec 16"

Anchorage Natural Resources Extraction Study
Anchorage Bowl
Location Map No. 7

T 12N R. 3W Sec 17, 19 Grids 2532, 2631 Scale 1"=1000'

Pit No.	Description	Size	Status	Remarks
2532-1	N. of O'Malley, btwn Old & New Seward Hwy	20 Acres	Expired	Minor Dumping
2631-1	AS&G - Klatt Road plant	50 Acres	Active	Gravel brought by train from Matanuska Valley: Max. capacity of train = 6400 tons/day
2631-2	W. of Old Seward; E. of Railroad; at O'Malley	20 Acres	Dormant	Eyescore; Minor Dumping

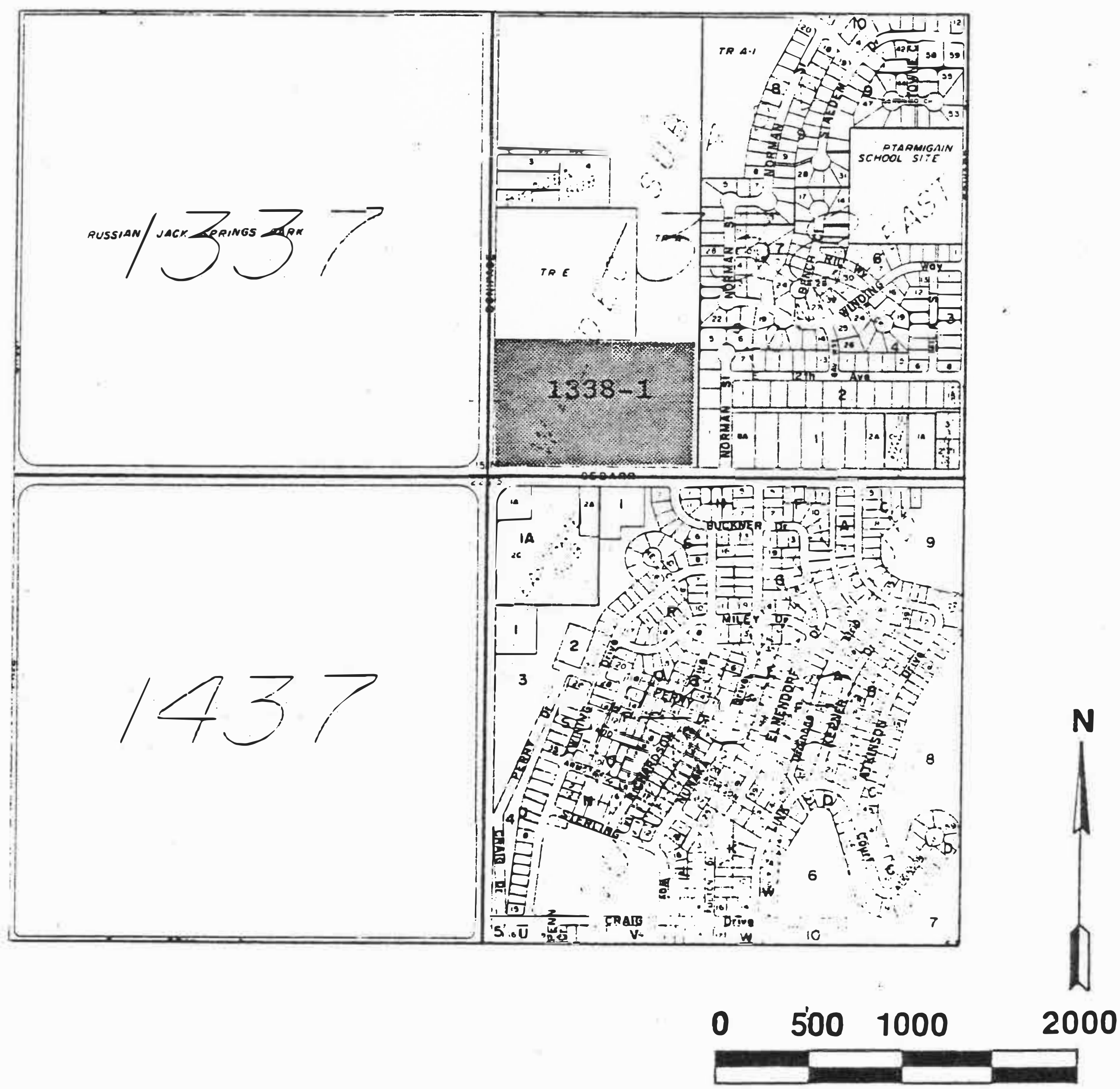
Anchorage Natural Resources
Extraction Study
Anchorage Bowl
Location Map No. 8



T 12N R 3W Sec 21 Grids 2634

Pit No.	Description	Size	Status	Remarks
2634-1	Pioneer Sand & Gravel	80 Acres	Active	Approx. 1,500,000 cu. yds. of gravel in reserve

Anchorage Natural Resources
Extraction Study
Anchorage Bowl
Location Map No. 9

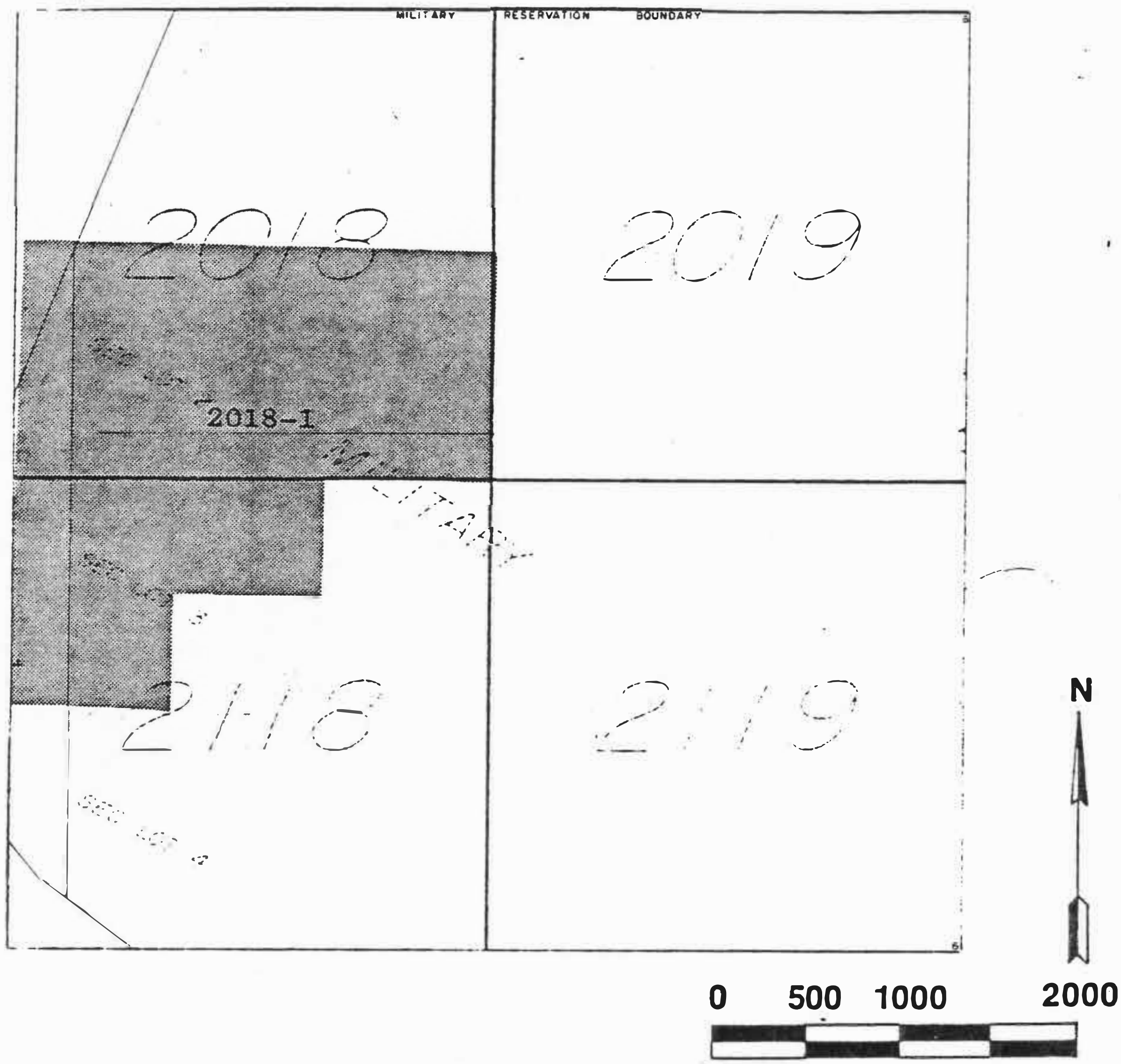


Scale 1"=1000'

T 13N R 3W Sec 14 Grids 1338

Pit No.	Description	Size	Status	Remarks
1338-1	NE corner of DeBarr and Boniface	20 Acres	Expired Gas Station storage Yard at SW corner; No future plans	Minor Dumping

Anchorage Natural Resources
Extraction Study
Anchorage Bowl
Location Map No. 10



T 12N R 4W Sec 6 Grids 2018, 2118

Pit No.	Description	Size	Status	Remarks
2018-1	Point Campbell - at end of East-West Runway	120 Acres	Active	Approx. 1,500,000 cu. yds. of gravel in reserves. This has been requested by DOT for Road Improvements near Airport.

Turnagain Arm

A number of material sites exist along Turnagain Arm (see Figure I.1), which have been utilized by the State, BLM, Forest Service, and Alaska Railroad. In general, there appears to be limited potential for the majority of these sites. Either limited size or difficult access are present in almost all cases, with the possible exception of TA-4 (M.S. 31-2-021-1), located at approximately M.P. 98 on the Seward Highway. This is a D.O.T. site located immediately adjacent to the highway, and has never been opened. It abuts a site utilized by the Alaska Railroad for maintenance material, and probably contains material similar to that which is exposed in the A.R.R. site. Visual impact at this site would be extremely high.

The only active material source in this study area which can be recommended for further study is Glacier Creek, TA-5. This stream has a high potential for flooding throughout its length, due to its extreme aggrading characteristics (see Recharge Analysis, Section III, for Glacier Creek). Gravel is presently being mined from site TA-5 in an area adjacent to the Girdwood Airport. This practice should be continued and the amount of suitable material and extent of area mined should be maximized. Drawbacks to full scale development of this site are lack of a suitable access route and annoyance to local residents (noise, dust, visual impacts and safety hazards). Continued excavation, however, would serve to maintain a more constant stream bed elevation, particularly in the reach adjacent to and immediately upstream of the City of Girdwood. Mining of the stream bed would reduce the flooding potential. The recharge capacity of Glacier Creek has been analyzed on a preliminary basis only. Our opinion is that more material can be mined than is presently being extracted. An in-depth study and monitoring program is recommended if this site is to be considered as a future source. The location suggested for TA-5, on Location Map No. 12, is designated as a Wetlands Preservation Area (figure 2-4, page 2-6, of the Anchorage Wetlands Management Plan). Prior to further study of this site for recharge capacity, the wetlands preservation designation should be reconciled.

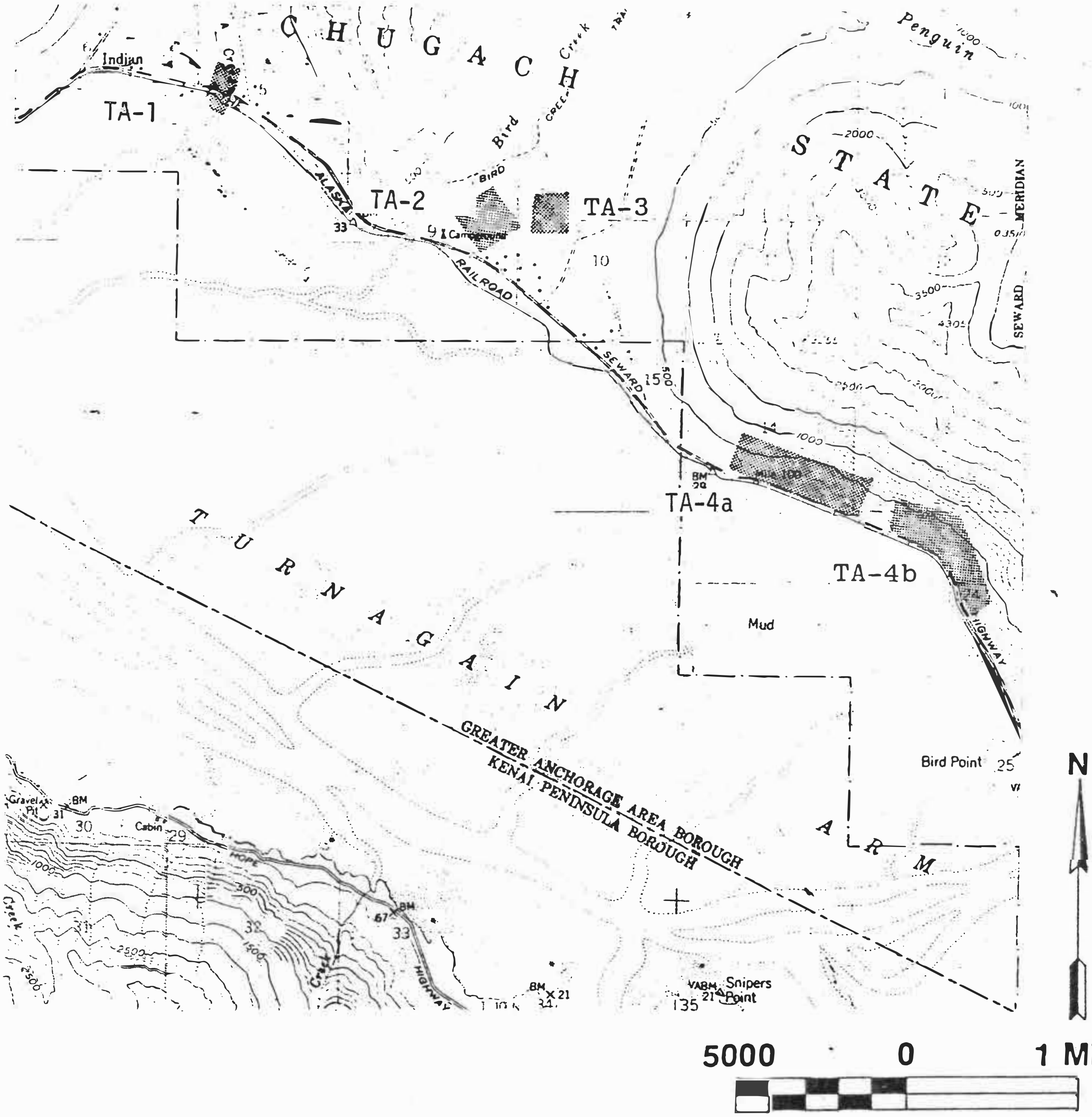
The State of Alaska maintains a pit just south of Girdwood, TA-6. This pit provides maintenance material for the area and continued operation is anticipated. Exploration for additional sites in the Turnagain Arm area could locate some additional amounts of material, but exploration and development costs to extract significant volumes would be very high. In most instances, the topography of the area is such that visual impact would be extreme at the upland sites and environmental and ecological investigations would be required for any new in-stream sites.

All sites in this area which have been investigated are summarized in Table II.2, Summary of Turnagain Arm. Location Maps for each pit follow directly after Table II.2. These maps include a brief description of the pit and general remarks. For a complete assessment of impacts and benefits, please refer to the Turnagain Arm Area Assessment Matrices in Appendix J.

TABLE II.2 - SUMMARY OF TURNAGAIN ARM

PIT NO.	APPROX. LOCATION	SIZE	STATUS	REMARKS
TA-1	Indian Creek	5 acres	Presently dormant	Less than 5,000 cu.yd./year
TA-2	0.2 miles east of Bird Creek; 400 ft. north of Seward Highway	11.5 acres	Presently used as storage yard for Wilder Construction	Approx. 23,000 c.y. remaining
TA-3	0.3 miles east of Bird Creek; 300 ft. north of Seward Highway	2.5 acres	Use shall cease 12-31-82; Restoration comp. 9-1-83	30,000-40,000 c.y. available
TA-4	Approx. MP98 Seward Highway	75 acres 60 acres	ARR has permit DOT has permit	Not a viable future source
TA-5	Glacier Creek	100 acres	DNR issues permits to private parties	16,000 cu.yd./year (see text & Recharge Analysis)
TA-6	0.5 mi. east of Girdwood; 0.3 mi. south of Seward Highway	15 acres	Maint. sand for Girdwood (DOT)	Less than 5,000 cu.yd./year
TA-7	Portage Creek	5 acres	Used for reconstruction of Seward Highway; dormant	Not a viable future source
TA-8	Bird Point	10 acres	Rip rap source for public purpose projects	20,000 cu.yd. proven
TA-9	Approx. MP92 Seward Highway	15 acres	No activity noted	Not a viable future source
TA-10	Peterson Creek	15 acres	Fractured bedrock; Inaccessible; dormant	Not a viable future source
TA-11	Approx. MP81.8 Seward Highway	10 acres	Fractured bedrock; Inaccessible; dead	Not a viable future source
TA-12	Placer River	N/A		Not a viable future source

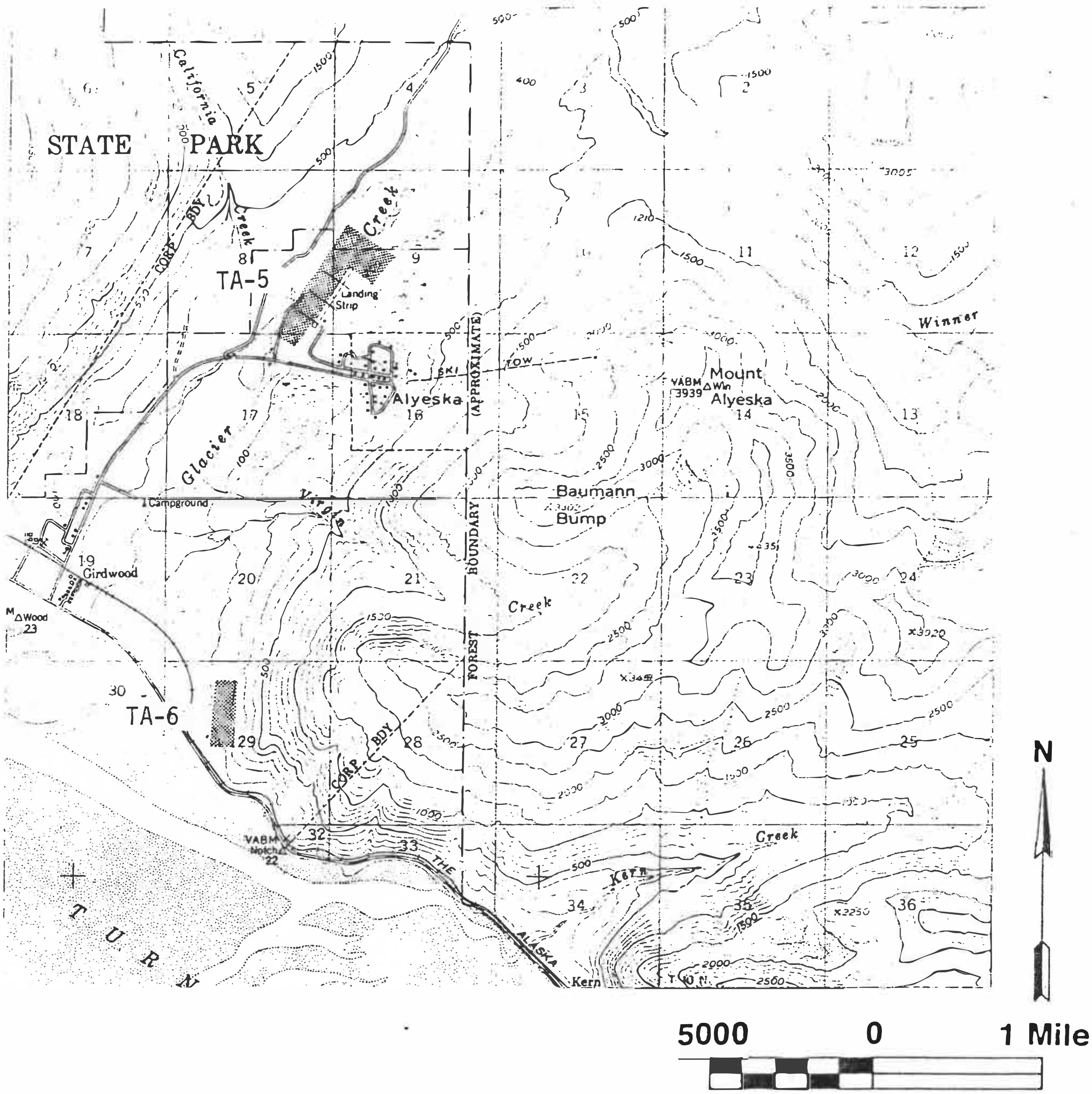
Anchorage Natural Resources Extraction Study
Turnagain Arm Area
Location Map No. 11



T 10N R 1W Sections 5, 9, 10, 14, 24

Pit No.	Description	Size	Status	Remarks
TA-1	Indian Creek	5 Acres	Dormant	Not a recommended future source
TA-2	.15 mi E. of Bird Creek 400 ft. N. of Seward Highway	11.5 Acres	Dormant	Approx. 23,000 cu. yds. remaining.
TA-3	.3 mi. E. of Bird Creek 400 ft. N. of Seward Highway	2.5 Acres	Active	30,000-40,000 cu. yds. available
TA-4	Approximately MP 98 Seward Highway	75 Acres 60 Acres	a) ARR has permit b) DOT has permit	Not a recommended future source

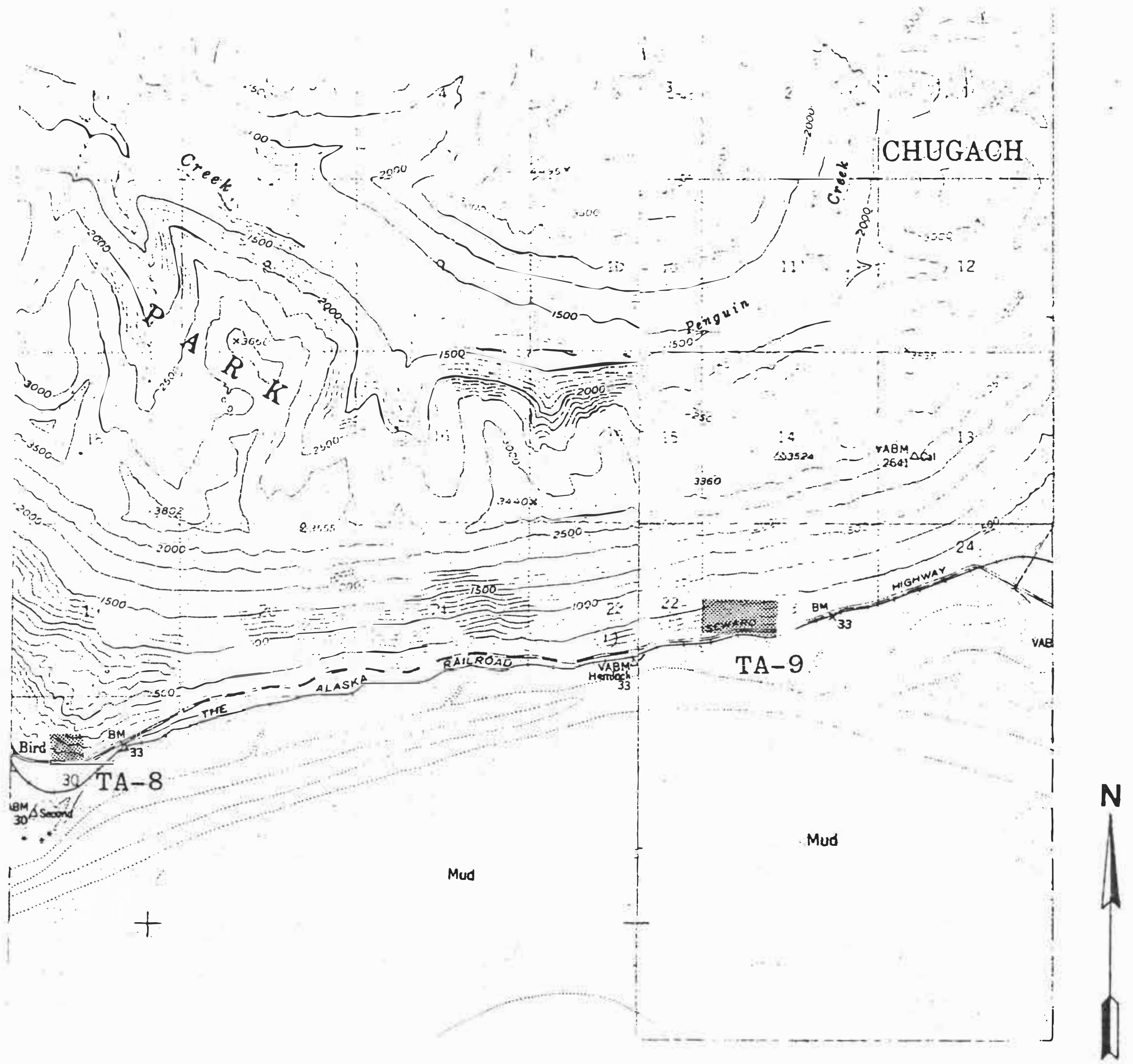
Anchorage Natural Resources Extraction Study Turnagain Arm Area Location Map No. 12



T 10N R 2E Sections 8, 9, 29

Pit No.	Description	Size	Status	Remarks
TA-5	Glacier Creek	100 Acres	16,000 cu. yd/yr. currently permitted	200,000 to 800,000 cu yd/yr. available depending on natural recharge
TA-6	1 mi. E. of Girdwood 1/4 mi. N. of Seward Highway	40 Acres	Maintenance sand for Girdwood (DOT)	Less than 5000 cu. yds per year extracted; no mitigation required

Anchorage Natural Resources
Extraction Study
Turnagain Arm Area
Location Map No. 13



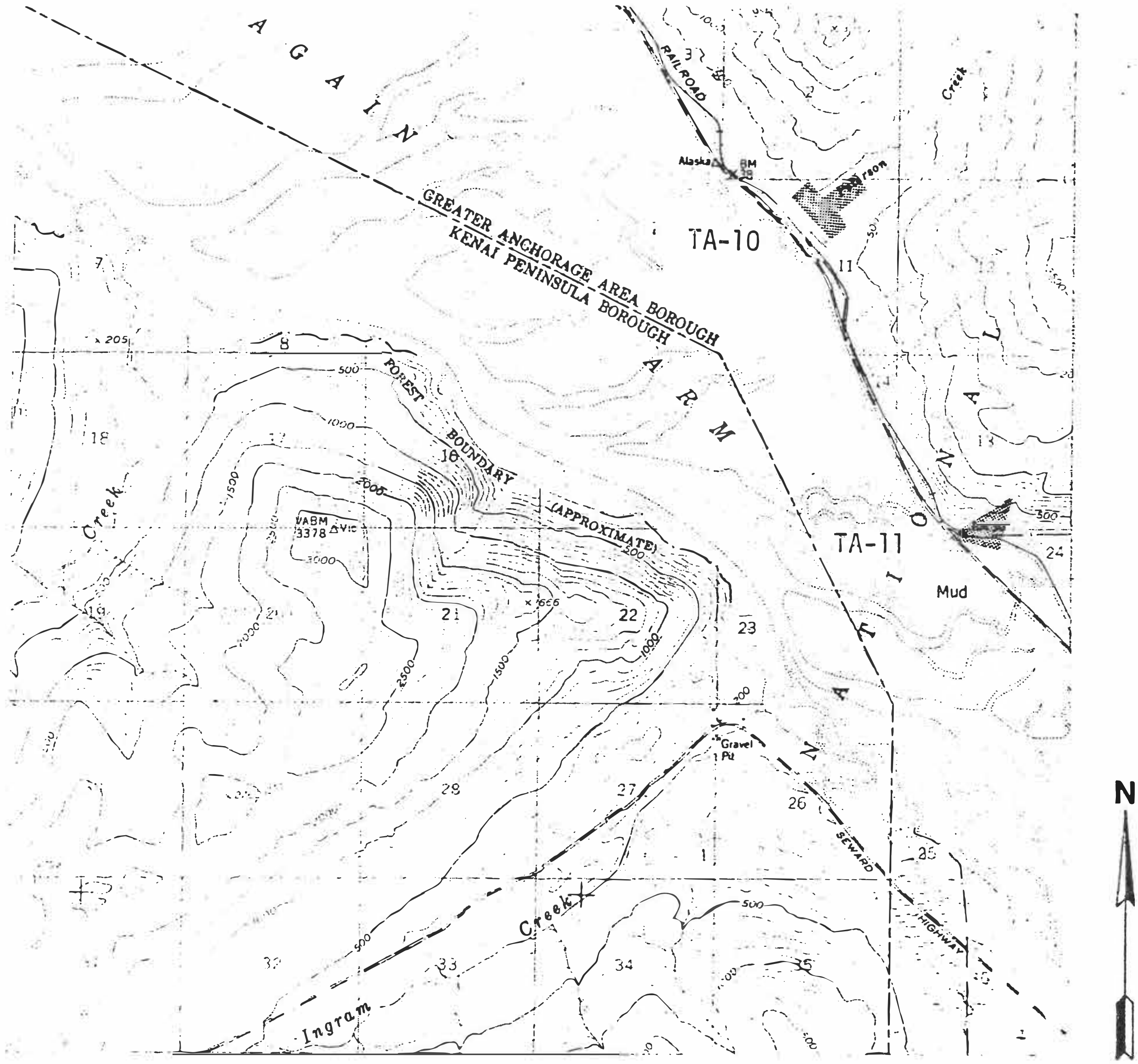
5000 0 1 Mile

Scale: 1" = 1 Mile

T 10N R 1E Sections 23, 30

Pit No.	Description	Size	Status	Remarks
TA-8	Bird Point	10 Acres	rip rap source for public purpose projects	20,000 cu. yds. available
TA-9	Approximately MP-92 Seward Highway	15 Acres	No activity noted	Not a recommended future source, No Problems

Anchorage Natural Resources Extraction Study
Turnagain Arm Area
Location Map No. 14



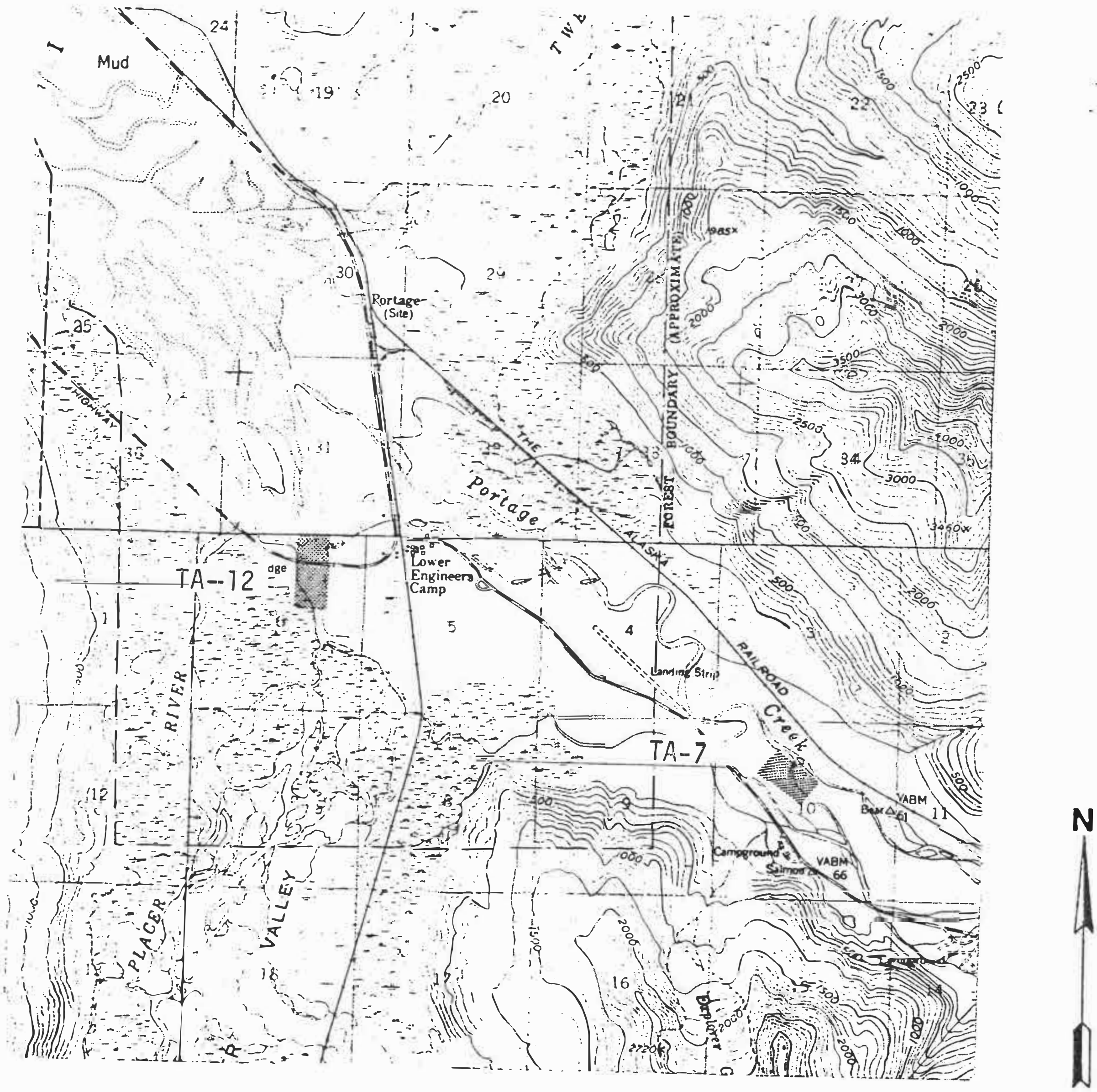
5000 0 1 Mile

Scale: 1" = 1 Mile

T 9N R 2E Sections 11, 13

Pit No.	Description	Size	Status	Remarks
TA-10	Peterson Creek	15 Acres	Dormant, Fractured bedrock, inaccessible	Not a recommended future source. No problems.
TA-11	Approximately MP 81.8 Seward Hwy	10 Acres	Dormant, Fractured bedrock, inaccessible	Not a recommended future source. No problems.

Anchorage Natural Resources Extraction Study
Turnagain Arm Area
Location Map No. 15



T 8N **R** 3W **Sections** 6, 10

Pit No.	Description	Size	Status	Remarks
TA-7	Portage Creek	15 Acres	Dormant, used for reconstruction of Seward Hwy.	Not a recommended future source, No problems.
TA-12	Placer River	20 Acres	Former DOT source	Not a recommended future source heavily silted. No Problems

Eagle River - Eklutna

Reserves of sand and gravel are available in the Eagle River-Eklutna area. Existing extraction and processing operations should continue to provide economical construction materials as the area's growth rate, including the Anchorage Bowl, accelerates. Materials for asphalt, concrete, and other classified material, some in pit-run form, are produced in well-established extraction sites concentrated along the Old Glenn Highway. The Artillery Road site, ER-1, has a considerable amount of pit run and, with special processing such as washing, could produce classified material. The Eklutna River Floodplain, ER-9, and the Alaska Railroad Reserves, ER-10, are possible primary future locations for sand and gravel. All sites in this area which have been investigated are summarized in Table II.3, Summary of Eagle River-Eklutna. Location Maps for each pit follow directly after Table II.3. These maps include a brief description of the pit and general remarks. For a complete assessment of impacts and benefits, please refer to the Eagle River-Eklutna Area Assessment Matrices in Appendix J.

Extraction site ER-10, which is on Federal land (Alaska Railroad) and is currently being worked by a private contractor, may become economically infeasible within the next two years. This, despite a number of positive features:

1. The contractor currently working on the site will remove approximately 500,000 cubic yards, by 1984, after which there will still be 1.5 million cubic yards remaining.

2. The site has no visual impact on either residential areas or major highways, and has good access.

3. The site can be worked as shallow excavation over a large area, precluding the need for any deep excavation.

The problem with this extraction site (ER-10) is that it will likely become the property of Eklutna, Inc., as a result of the Native Land Settlement Act.. Although the land will belong to the Village Corporation, the subsurface rights will remain within the Regional Corporation, Cook Inlet Region, Inc. Cook Inlet Region, Inc. has indicated that they will most likely continue operation of this site commencing in the spring of 1985.

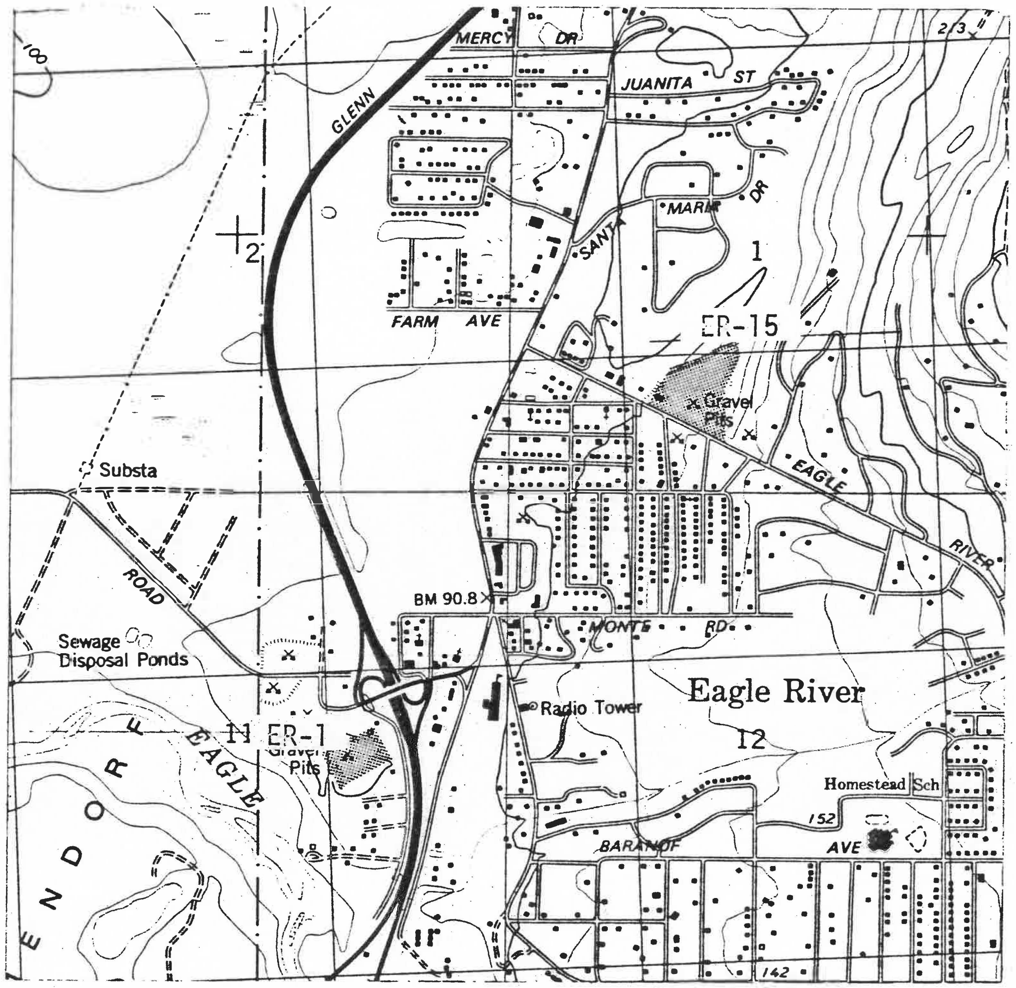
The Eklutna River site (ER-9) is presently inactive, although it was previously being worked. Although it has not been possible to ascertain the reason for stopping work, the village-regional conflict may be at least partly responsible. Other problems associated with this site are discussed in Section III.F, Recharge Analysis.

In addition, both ER-9 and ER-10 lie within an area designated for special study per the Anchorage Wetlands Management Plan (AWMP), Figure 6-5, page 6-16. Conflicts between AWMP and the recommendations contained herein must be resolved prior to any development of ER-9 or expansion of ER-10.

TABLE II.3 - SUMMARY OF EAGLE RIVER-EKLUTNA

PIT NO.	DESCRIPTION	SIZE	STATUS	REMARKS
ER-1	Artillery Road & Glenn Hwy., Eagle River	10 acres	Presently inactive	1,000,000 c.y. available
ER-2	N. Birchwood Loop & Beverly Drive	5 acres	Expired	Steep slopes, unsightly stockpiles
ER-3	Moose Horn Bus Garage Old Glenn Hwy, Chugiak	30 acres	Expired	No noted problems
ER-4	Klondike, Old Glenn Hwy., Chugiak	50 acres	Active	Adequate reserves for indefinite concrete production
ER-5	Stephan & Sons; Old Glenn Hwy.; Chugiak	40 acres	Presently inactive	Approx. 250,000 c.y. in reserves
ER-6	Northern Steel; Old Glenn Hwy., Chugiak	40 acres	Active	Approx. 500,000-750,000 c.y. (1,500,000 tons) in reserves
ER-7	Central Paving Products (Rogers & Babler) Old Glenn Hwy., Chugiak	40 acres	Active	Approx. 500,000-750,000 c.y. (1,500,000 tons) in reserves
ER-8	Izaak Walton League - Gun Range Behind Birchwood Airport	5 acres	Operations to be complete 12-31-82	40,000 c.y. permitted
ER-9	MBE Gravel Company; Eklutna River Floodplain	80 acres	Presently Inactive	1,000,000 - 3,000,000 c.y. available
ER-10	Alaska Railroad Reserves; Adjacent to Eklutna River; Rogers & Babler	100 acres	Active	1,500,000 c.y. in reserves; as of 12-31-82

Anchorage Natural Resources Extraction Study
Eagle River/Chugiak Area
Location Map No. 16



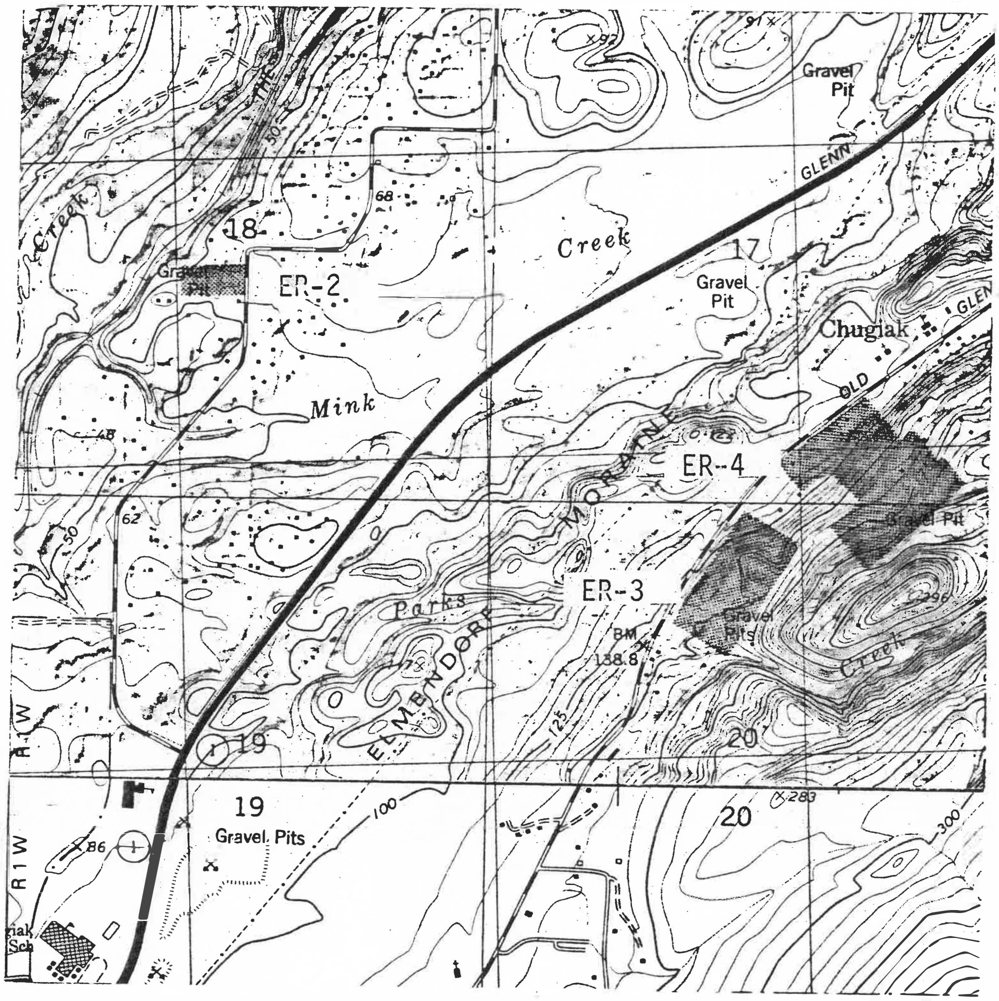
0 1000 2000 4000

Scale: 1:25,000
(Approx. 1"=2000')

T 14N R 2W Sections 1, 2, 11, 12

Pit No.	Description	Size	Status	Remarks
ER-1	Artillery Road and Glenn Hwy	10 Acres	Presently Inactive	1,000,000 Cu. yds of gravel available
ER-15	N. side of Eagle River Loop	15 Acres	Expired	Minor dumping

Anchorage Natural Resources Extraction Study
Eagle River/Chugiak Area
Location Map No. 17



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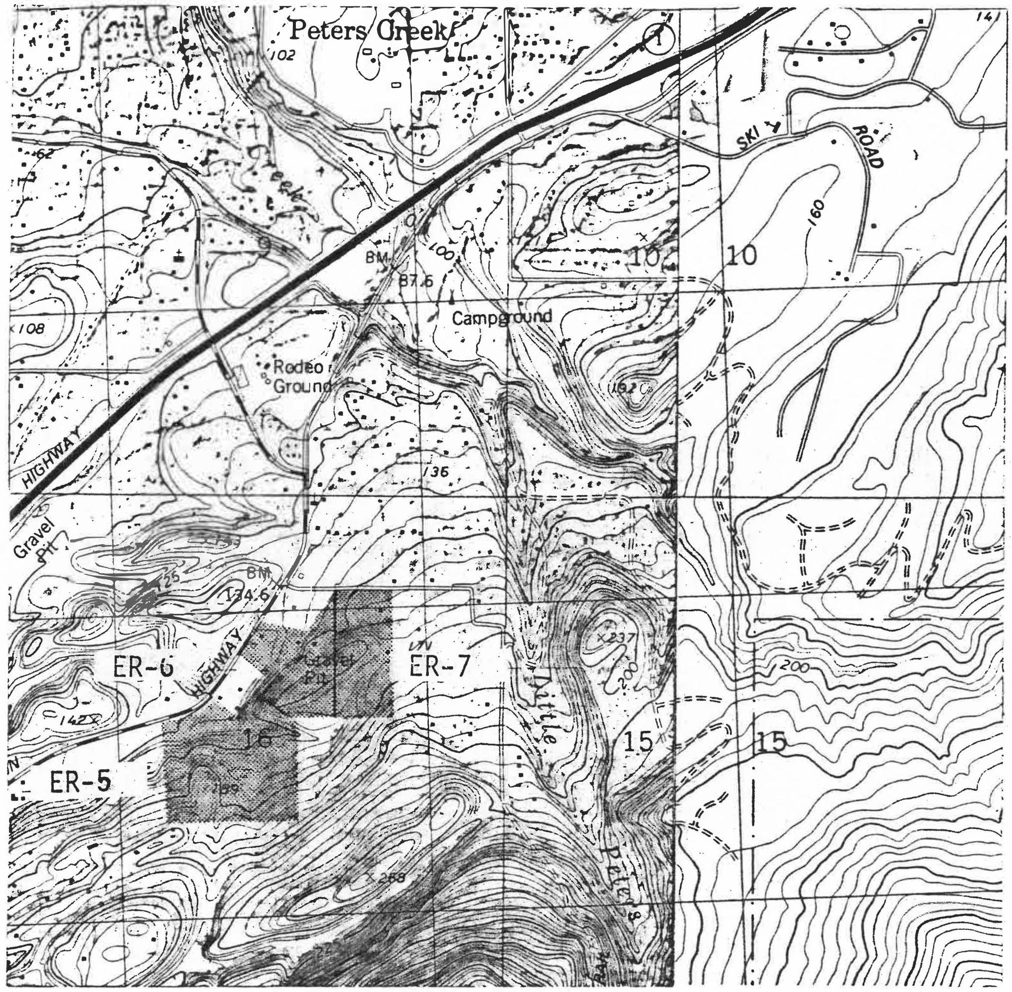
0 1000 2000 4000

Scale: 1:25,000
(Approx. 1"=2000')

T 15N **R** 1W **Sections** 17, 18, 19, 20

Pit No.	Description	Size	Status	Remarks
ER-2	N. Birchwood Loop and Beverly Drive	5 Acres	Expired	Steep slopes, unsightly stockpiles
ER-3	Moose Horn Bus Garage	30 Acres	Expired	No noted problems
ER-4	Klondike	50 Acres	Active	Adequate reserves for indefinite concrete production.

Anchorage Natural Resources Extraction Study
Eagle River/Chugiak Area
Location Map No. 18



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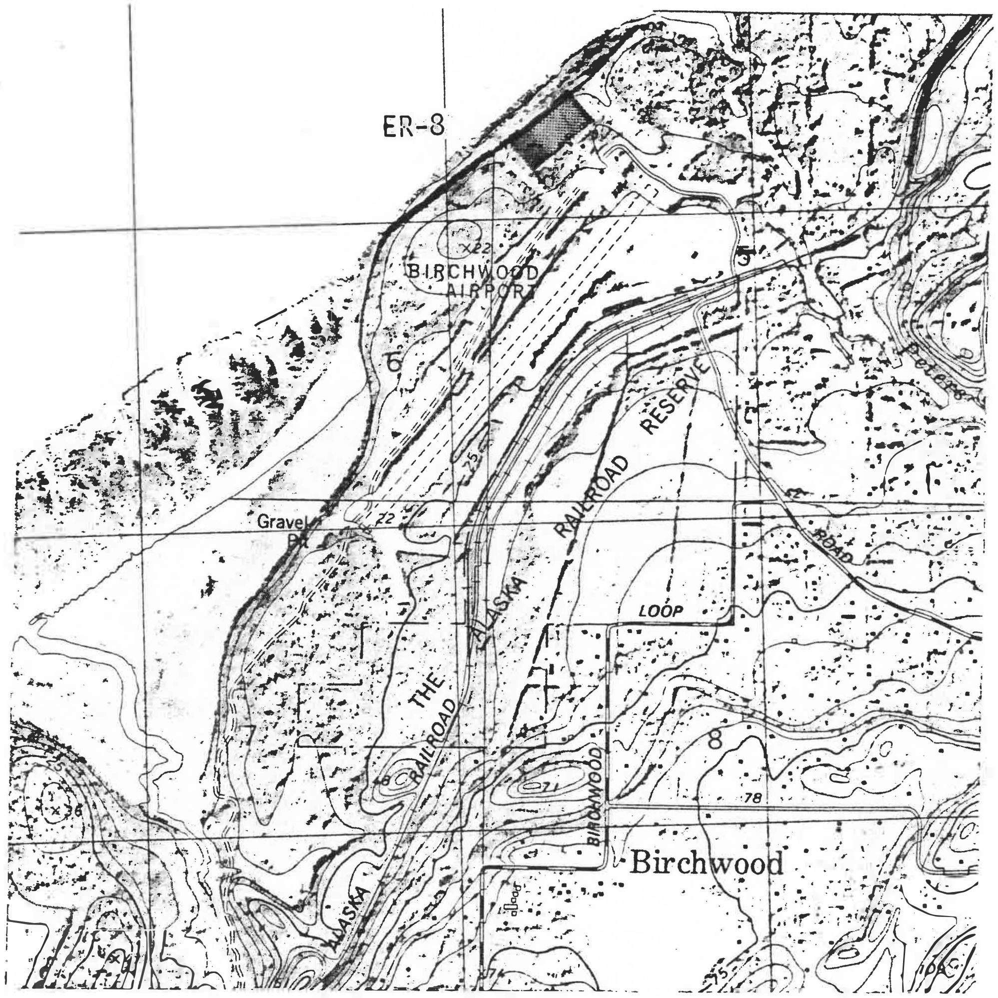
Scale: 1:25,000
(Approx. 1"=2000')

T 15N R 1W Sections 9, 10, 15, 16

Pit No.	Description	Size	Status	Remarks
ER-5	Stephan and Sons	40 Acres	Presently Inactive	Approx. 250,000 cu. yd in reserves
ER-6	Northern Steel	40 Acres	Active	Approx. 500,000-750,00 cu.yds(1,500,000 tons) i reserves
ER-7	Central Paving Products	40 Acres	Active	Approx. 500,000-750,00 cu. yds. (1,500,000 ton in reserves

Anchorage Natural Resources Extraction Study
Eagle River/Chugiak Area
Location Map No. 19



N

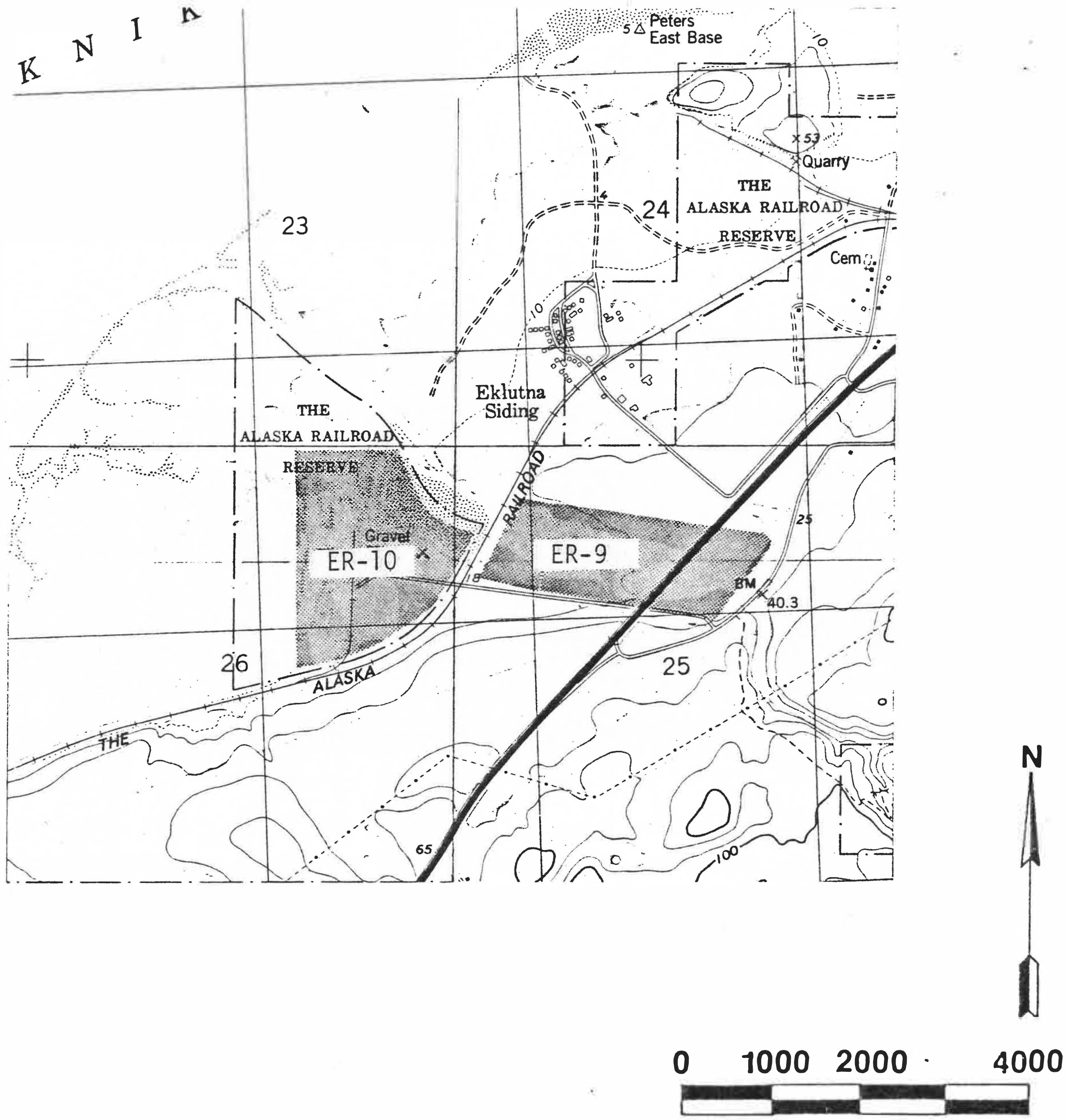
0 1000 2000 4000

Scale: 1:25,000
(Approx. 1"= 2000')

T 15N R 1W Sections 5, 6, 7, 8

Pit No.	Description	Size	Status	Remarks
ER-8	Izaak Walton Recreation Park, Birchwood Airport	5 Acres	Operations to be Complete 12-31-82	40,000 cu. yds. permitted

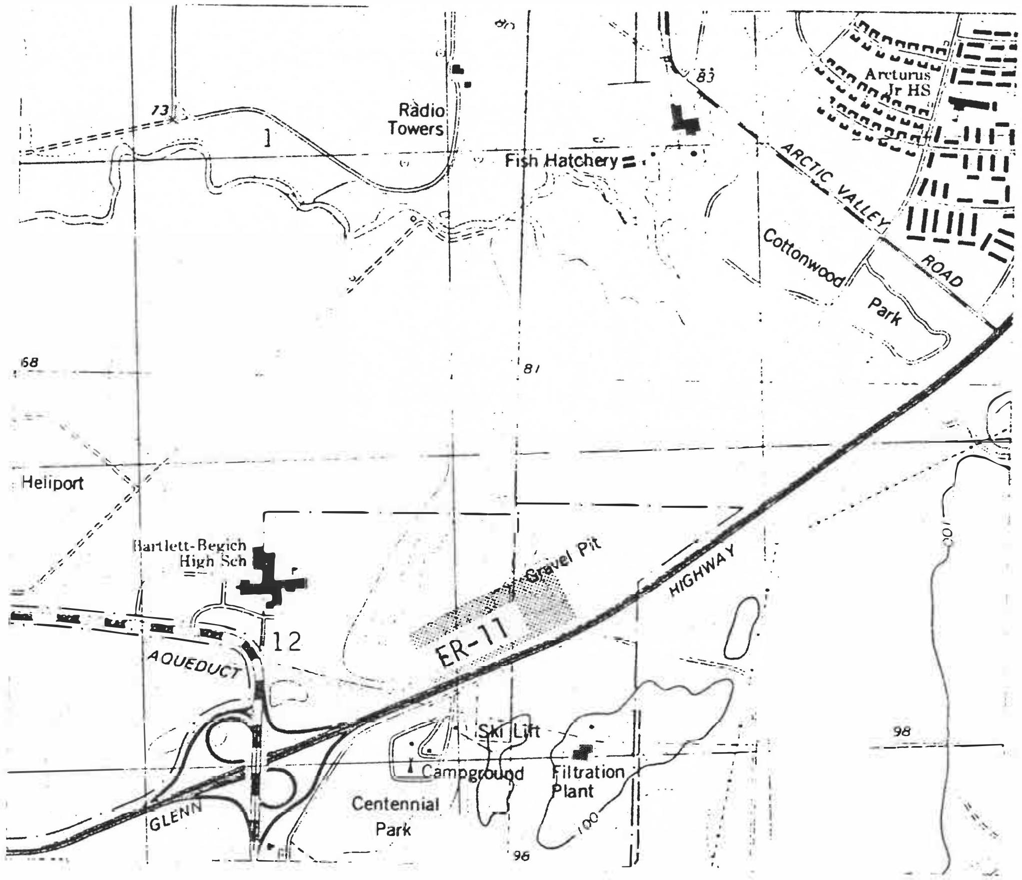
Anchorage Natural Resources Extraction Study
Eagle River/Chugiak Area
Location Map No. 20



T 16N R 1W Sections 23, 24, 25, 26

Pit No.	Description	Size	Status	Remarks
ER-9	Eklutna River Floodplain	80 Acres	Presently Inactive	1,000,000 to 3,000,000 cu. yds. available, depending on natural recharge.
ER-10	Alaska Railroad Reserves	100 Acres	Active	1,500,000 cu. yds. gravel in reserves as of 12-31-84.

Anchorage Natural Resources
Extraction Study
Eagle River/Chugiak Area
Location Map No. 21



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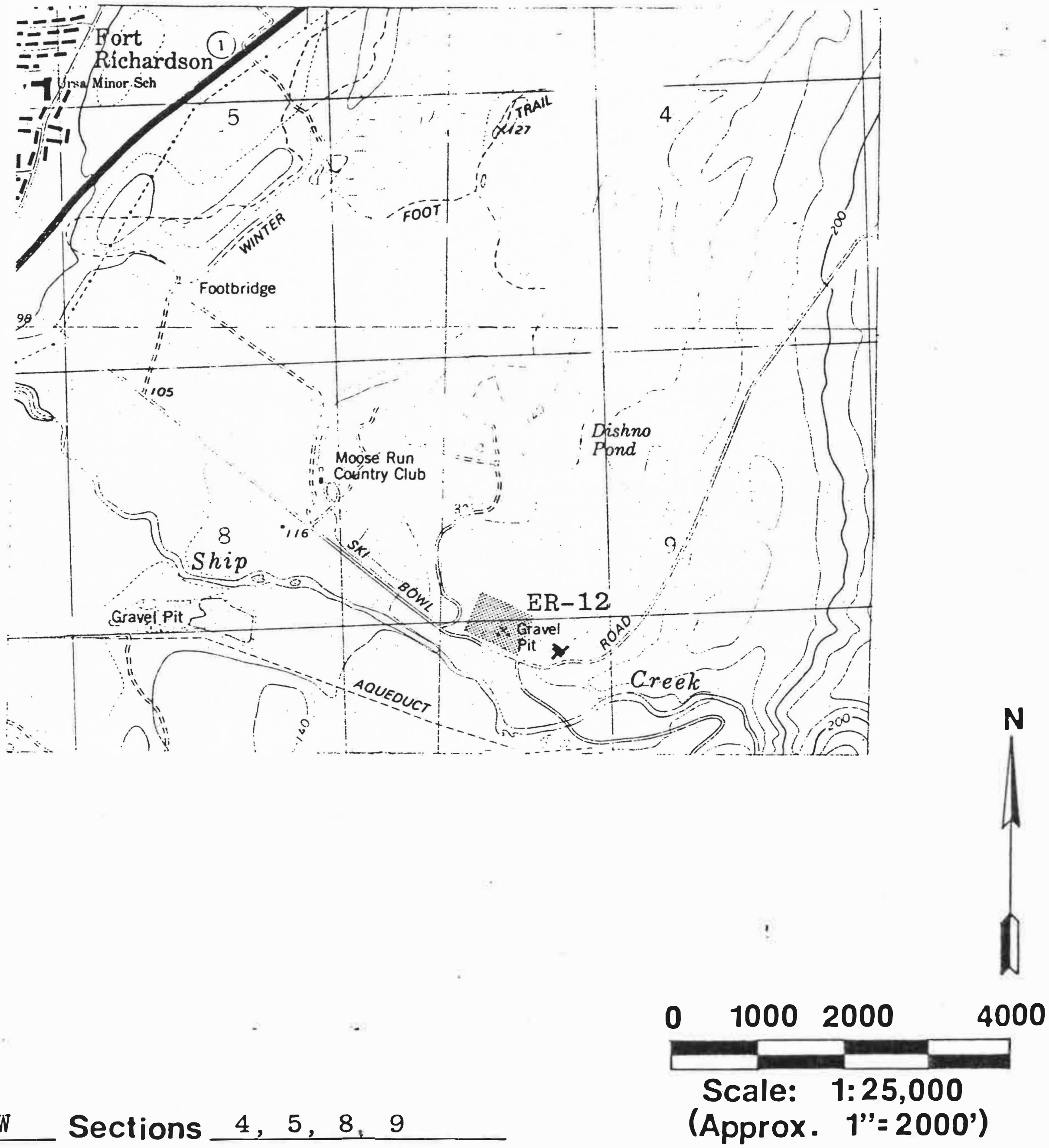
0 1000 2000 4000

Scale: 1:25,000
(Approx. 1"=2000')

T 13N R 3W/2W Sections 1, 12/6, 7

Pit No.	Description	Size	Status	Remarks
ER-11	Adjacent to Glenn Hwy; Near Bartlett High School	25 Acres	Expired	Not a recommended future site; No problems noted.

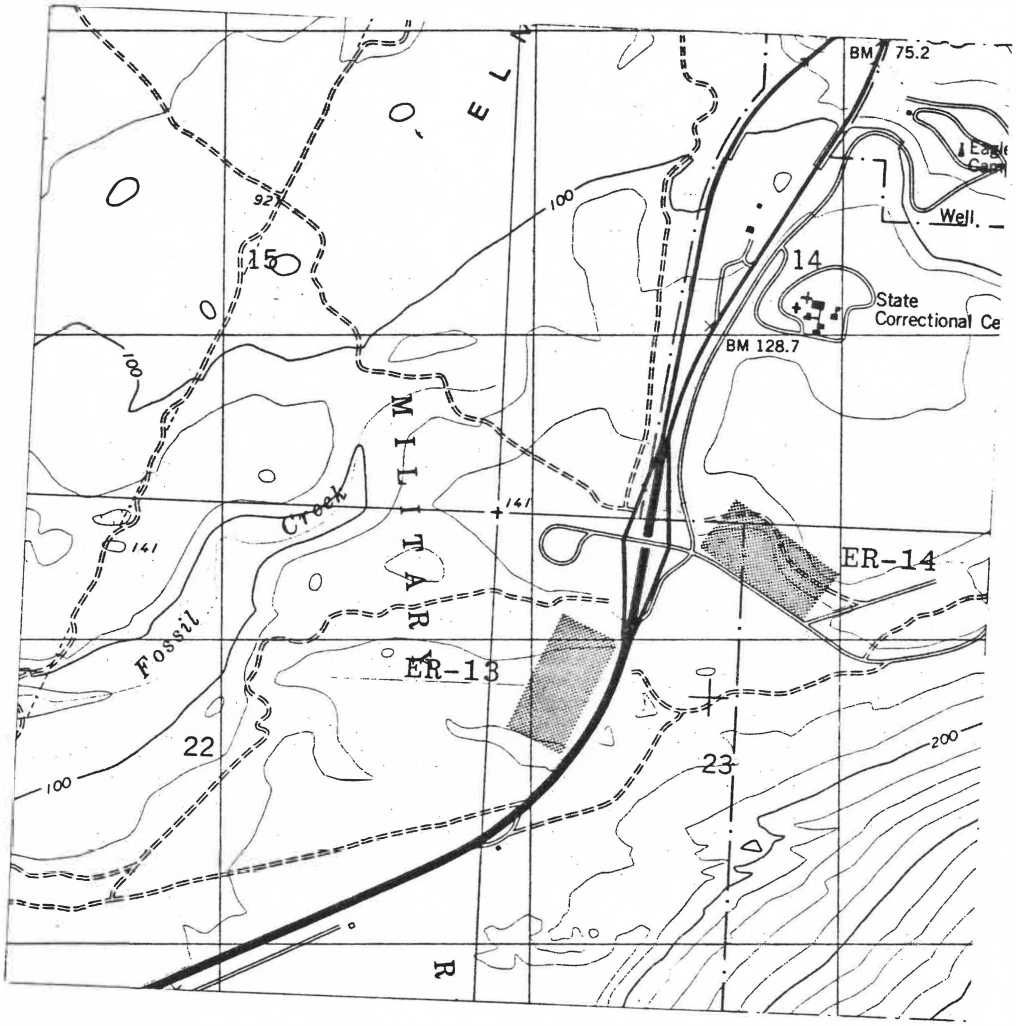
Anchorage Natural Resources
Extraction Study
Eagle River/Chugiak Area
Location Map No. 22



T 13N R 2W Sections 4, 5, 8, 9

Pit No.	Description	Size	Status	Remarks
ER-12	Arctic Valley Road	5 acres	Army may use for maintenance	No noted problems

Anchorage Natural Resources Extraction Study
Eagle River/Chugiak Area
Location Map No. 23



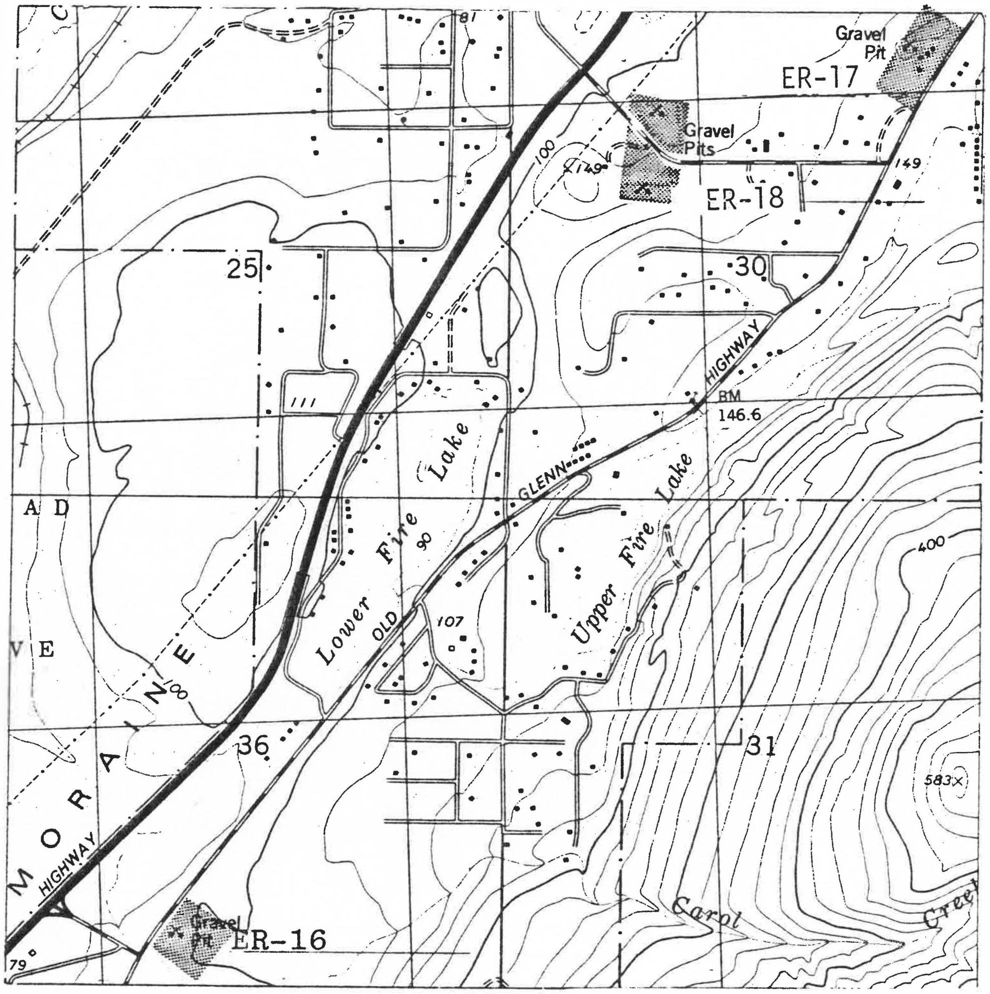
0 1000 2000 4000

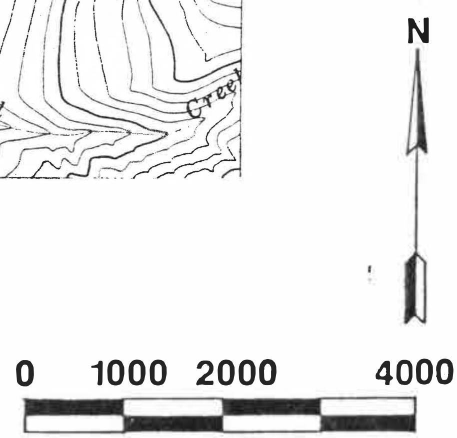
Scale: 1:25,000
(Approx. 1"= 2000')

T 14N R 2W Sections 14, 15, 22, 23

Pit No.	Description	Size	Status	Remarks
ER-13	Adjacent to Weigh Station, W. side of Glenn Hwy.	20 Acres	Dormant	No Noted Problems
ER-14	N. side of Hiland Drive	20 Acres	Expired	Dumping; Not a viable future source (no good material)

Anchorage Natural Resources
Extraction Study
Eagle River/Chugiak Area
Location Map No. 24



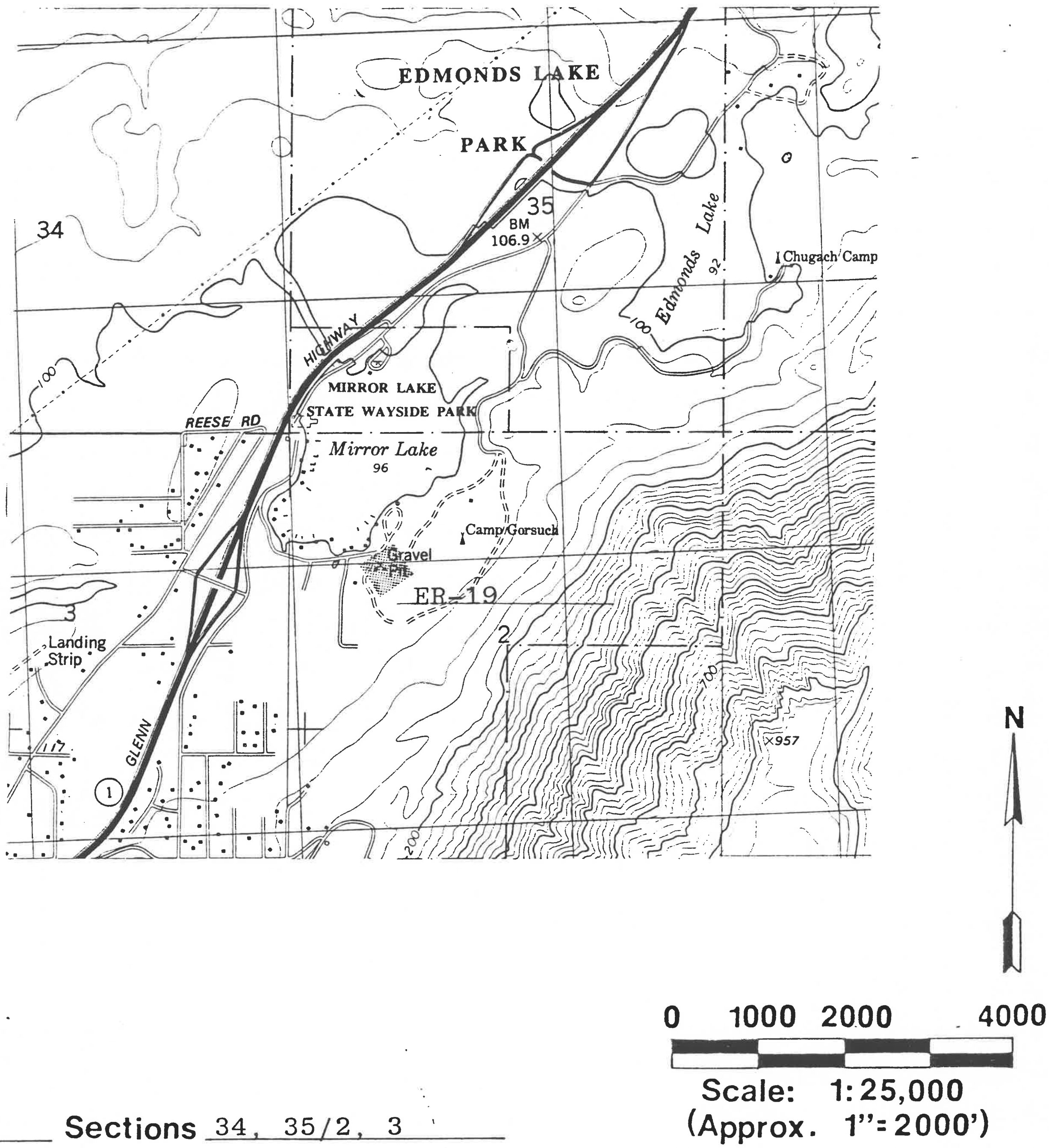


Scale: 1:25,000
(Approx. 1"=2000')

T 15N **R** 2W/1W **Sections** 25, 36/30, 31

Pit No.	Description	Size	Status	Remarks
ER-16	Adjacent to Old Glenn Hwy; N. of Eagle River	10 Acres	Expired	No noted problems; Old Glenn Hwy Improvements encroaching on pit.
ER-17	Adjacent to Old Glenn Hwy	15 Acres	Expired	Steep Slopes
ER-18	N. and S. of access road btwn. Old & New Glenn Hwys	15 Acres	Expired	No noted problems; Pits are approx. 50 feet above road grade.

Anchorage Natural Resources
Extraction Study
Eagle River/Chugiak Area
Location Map No. 25



T 16N/15N R 1W Sections 34, 35/2, 3

Pit No.	Description	Size	Status	Remarks
ER-19	S. of Mirror Lake	3 Acres	Dormant	Not a recommend future source; No noted problems

Sand Lake

Although large quantities of sand and lesser quantities of gravel remain in some active pits in the Sand Lake Area, the availability of the material is limited. Active extraction sites in the Sand Lake area, designated as SL-1 through SL-10, are currently operating under Conditional Use Permits which expire December 31, 1982. Restoration is to follow, according to approved restoration plans. These plans specify finish grades and elevations for each pit. In some cases, the approved final topography cannot be achieved without the extraction of additional material. Thus, if an extension to the existing permits is not granted, restoration plans must be revised.

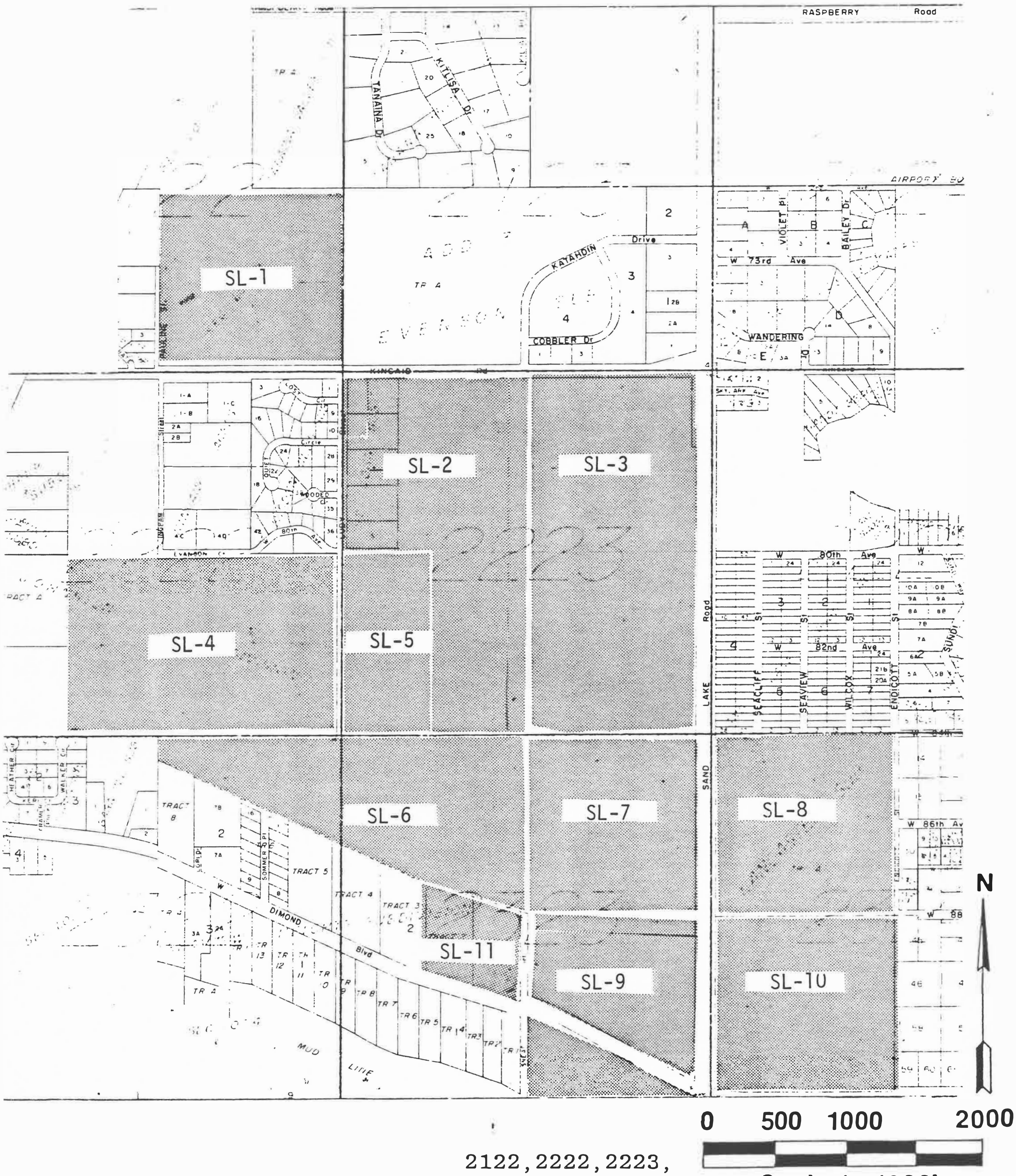
As required by this contract, the Sand Lake pits have been studied independently. Report #2 entitled, SAND LAKE AREA COMPREHENSIVE DEVELOPMENT PLAN, is a separate document devoted entirely to the Sand Lake pits.

All sites in this area which have been investigated are summarized in Table II.4, Summary of Sand Lake. Location Maps for each pit follow directly after Table II.4. These maps include a brief description of the pit and general remarks. For a complete assessment of impacts and benefits, please refer to the Sand Lake Area Assessment Matrices in Appendix J.

TABLE II.4 - SUMMARY OF SAND LAKE AREA

PIT NO.	DESCRIPTION	SIZE	STATUS	REMARKS
SL-1	MIL Pit - Kincaid Road	40 acres	Dormant; To be developed	132,000 c.y., Type II remaining
SL-2	Sand Lake Aggregate	60 acres	Active (Types II, III, NFS); To be developed as R-2A, contingent on extension of special exception & concept approval	3,000,000 c.y. F-1 & F-2; 580,000 c.y.Types II, & III remaining as of 12-31-82
SL-3	Irvin Evenson Pit	80 acres	Active (NFS sand)	400,000 - 800,000 c.y. remaining (Stephan & Sons)as of 12-31-82 if Sand Lake Road is lowered
SL-4	Skyhills Pit	60 acres	Dormant; to be developed	Remaining gravel to be used in development of pit
SL-5	Susky Pit (A S & G)	20 acres	Dormant; to be restored and developed as R-1A	Depleted
SL-6	Seaview Pit	56 acres	Active (NFS sand); to be devel.	50,000 c.y.remaining
SL-7	Harold Wright Pit (Rogers & Babler)	40 acres	Active (NFS sand - F-4); To be restored & developed as R-1A	50,000 - 80,000 c.y. remaining if Sand Lake Road is lowered
SL-8	A S & G	40 acres	Active (NFS sand - F-4); To be restored and sold	Depleted
SL-9	Stephan & Sons	30 acres	Active (NFS sand - F-4)	100,000 - 160,000 c.y. remaining as of 12-31-82
SL-10	RCJ Pit	40 acres	Active (F-4)	42,000 c.y. remaining as of 12-31-82
SL-11	Alice Tallman	10 acres	Proposed (Types I, II, III)	160,000 - 260,000 c.y. avail. if Snead Road is lowered

Anchorage Natural Resources
Extraction Study
Anchorage Bowl (Sand Lake)
Location Map No. 26



Scale 1"=1000'

T 12N R 3W Sec 4,9,10 Grids 2122,2222,2223, 2322,2323,2324

Pit No.	Description	Size	Status	Remarks
SL-1 through SL-11	See Sand Lake Area Summary Table			

Matanuska Valley

A primary source of classified sand and gravel material imported to the Anchorage area is shipped via the Alaska Railroad from the Matanuska Valley area. Although this source is located within the Matanuska-Susitna Borough and therefore outside of the study area for this report, it was our opinion that this source should be included under Existing Operations.

The Alaska Railroad has three trains serving the gravel industry. From mid-April until September, these trains make one trip per day generally five days per week (sometimes 6) with the following capacities:

1.	Central Paving Products 80 cars/train x 80 tons/car =	6,400 tons/day	3,830 cy/day
2.	Anchorage Sand and Gravel 80 cars/train x 80 tons/car =	6,400 tons/day	3,830 cy/day
3.	Alagco 60 cars/train x 75 tons/car =	4,500 tons/day	2,700 cy/day
	Total =	17,300 tons/day	10,360 cy/day

Washing operations take place in the Valley before the gravel is shipped. Once it is delivered to the Anchorage locations, 2028-1, 2130-1 and 2631-1 (refer to Table II.1), it is further processed (asphalt and concrete aggregate, base course and septic rock) and also sold as pit-run.

Shipping large quantities of gravel at once, by train, greatly alleviates the traffic problems caused by trucking minor amounts individually. It is an efficient overall method of delivering raw material to processing plants and/or stockpile areas. The gravel sources in the Matanuska Valley are extremely large; future supplies will be limited only by demand and the railroad's hauling capacity. It is therefore anticipated that, as other present gravel sources phase out, the railroad will continue to play a primary role in the development of Anchorage in the next 10 to 20 years.

The influence of the railroad, its capacity, and other factors involved with this operation are discussed further in other sections of this report.

B. ENVIRONMENTAL ANALYSIS

Introduction

Initially two formats were developed for the gathering and presentation of environmental data associated with each extraction site. These are the Field Inventory Data forms and the Area Assessment Matrices. A copy of the Field Inventory Data form is included in Appendix A. Please refer to Figure I.1 for the locations and designations of the sites within the study area.

Upon completion of the Field Inventory Data forms, an Area Assessment Matrix was completed for each general area and within the matrix each site was evaluated. The areas studied included Anchorage Bowl, Turnagain Arm, Eagle River/Eklutna and Sand Lake. Please refer to the four individual matrices in Appendix J.

The impact benefit assessment factors used were designed using the United States Geological Survey Circular 645, a standard procedure for evaluation of environmental impacts. In accordance with the specified method, the impact benefit assessment factors were grouped into three categories: physical/chemical; biological; and cultural. Since the list of factors provided under each category is comprehensive and intended to cover a wide range of situations, most of the factors were left unchanged for the purpose of this study. However, a few factors were irrelevant, and were either deleted or modified. Some categories were expanded. Factors that are beyond the scope of this study or addressed by previous management studies; or which would have required extensive comprehensive treatment were excluded. For example, a comprehensive biological study was not done. However, biological factors were included on the impact/benefit assessment, so that on future site specific planning and design efforts they can be addressed. Clearly, numerous other factors could be added to this assessment but were not due to previous coverage by other studies or relevance for this study. For example, it was suggested that water temperature and ocean impacts should be included. However, these issues were the subject of special studies, such as the 208 Water Quality Management Study and the MAUS Estuary Study. Therefore, these considerations were not included in the matrices. If significant impacts had been discovered during the inventory process that were not included in the matrices, additional factors would have been identified and either investigated or recommended for further study. The scope of work for this study is limited to an area-wide planning inventory and management study. It does not include detailed mining operation, planning or site specific design. Detailed mining operation planning is recommended for all future natural resource extraction sites.

Inventory Format

A field assessment was made of each gravel extraction site by using a 4-page Field Inventory Data questionnaire to provide a resume of basic information. The original Field Inventory Format questionnaires have been bound in three volumes and transmitted to the Municipality under separate cover, together with a complete set of slides and photographs taken at each site during the field data gathering process.

Basic data obtained on each extraction site included the assigned Pit Number; the type of operation; land owners of record; surrounding land uses within one-half mile; the developing trend in the area; total land area involved; traffic and circulation; equipment being used on-site; a description of the pit; visual problems; and a variety of other data pertinent to each operation. The field assessment was made by a qualified engineer or engineering technician.

The purpose of this on-site, visual, evaluation was to determine the quantities of available material and to identify conditions which would possibly require future mitigation. Sites included active, inactive and potential sources throughout the study area. Sites smaller than one acre or yielding less than 5,000 cubic yards were deemed insignificant and were excluded from the study.

Each pit was visited to determine whether an assessment was warranted. All active pits were evaluated, as were inactive or abandoned sites with environmental conditions (or activities) requiring mitigation. Inactive pits without apparent impacts were not evaluated; however, they were identified on location maps. Pits which have been redeveloped were neither evaluated nor identified on location maps.

Activities were identified at each site warranting an evaluation. For sites still being worked, activities or impacts included such items as excavation, processing, trucking and safety hazards. Typical activities or impacts at inactive or abandoned sites were waste disposal (dumping), safety hazards (steep slopes) and visual impact.

Area Assessment Matrix

Upon completion of the Field Inventory Data forms, the applicable information was transferred to the Area Assessment Matrix for its particular location within the study area. The four Area Assessment Matrices are included in the Appendix to this report.

Each site was evaluated, in terms of its activities, under three major impact/benefit classifications: Physical/Chemical; Biological; and Cultural. Additionally, each of these major headings were further divided into sub-classifications. Each sub-classification represents an impact or benefit resulting from an activity which would be associated with a particular operation. This activity may be beneficial or detrimental to the environment and therefore each activity was evaluated, on a scale of 1 to 10, for both impacts (-) and benefits (+). The importance of each impact or benefit was also evaluated on a scale of 1 to 10. Thus, an impact may be severe, for example, but of little consequence, or vice versa.

Rating of each activity on a scale of 1 to 10, either positively or negatively, indicates their impact level as applied to each pit. Assigning values to each impact or benefit of each activity was a subjective process. Care was taken to provide an accurate graphic representation of the influence of each pit on its surrounding environment.

During the initial process of investigating the various extraction sites, a total of 48 pits were evaluated. An additional 17 inactive sites were investigated but not evaluated. Locations are as follows:

Anchorage Bowl	23 Locations (14 active, potential, or requiring mitigation; 9 inactive, without apparent impacts)
Turnagain Arm	12 Locations (all active, potential, or requiring mitigation)
Eagle River/Eklutna	19 Locations (10 active, potential, or requiring mitigation; 9 inactive, without apparent problems)
Sand Lake	11 Locations (all active, potential, or requiring mitigation)

Evaluation of Extraction Sites

Since environmental impacts generated by the extraction of sand and gravel vary considerably and cannot be objectively evaluated, those requiring mitigation have been articulated in narrative form below.

Anchorage Bowl

Pit No.	Environmental Synopsis
1233-1	Anchorage S&G (1st and Orca), Slopes, especially along the east boundary (adjacent to the Martin Arms Apts.), should be stabilized according to the approved restoration plan.
1338-1	Northeast corner of DeBarr and Boniface - A minor amount of dumping has occurred. Proper disposal is needed.
1434-1	South of DeBarr, east of Lake Otis - On-site stockpiles should be removed. The land is for sale and will no doubt be developed in the near future.
1521-1	Pt. Woronzof (20 acres) - A comprehensive restoration plan is warranted. Slopes need to be stabilized. Special attention should be given to the culvert outfall to prevent the undermining of Pt. Woronzof Road. Safety and beautification measures (i.e., a guard rail along the bluff and grading and seeding of the pit area) are also recommended, as this area is used extensively by the public.
1734-1	East of Lake Otis, south of Providence Drive - The pit has been adequately restored.
1736-1	North of Chester Creek, east of Bragaw - The pit has been adequately restored.
1736-2	South of Chester Creek, east of Bragaw - This area is currently being developed. The water quality of the on-site lakes and Chester Creek should be maintained throughout the construction phase.
2018-1	Point Campbell at end of east-west runway - Environmental concerns and recommendations should be based on final decisions regarding ownership and future land use.
2028-1	Central Paving Products Plant - Traffic circulation at Dowling and Arctic is poor. A traffic signal would alleviate the problem.
2130-1	ALAGCO (68th and "C") - No problems requiring mitigation exist.
2135-1	Lore Rd., North (10 acres) - The pit is being brought to surrounding grade with poor quality fill (peat overburden and trees). Proper remedial measures should be taken if this land is to be developed as-is, such as consolidation over a number of years.

2234-1 Lore Rd. and Spruce St. (12 acres) - The steep slopes at the northern portion of Section 9 should be stabilized, or that entire area, brought to road grade. Stock piles on-site should be eliminated.

2235-1 Lore Rd., South Side (5 acres) - Eroding slopes on eastern boundary need to be stabilized. The bottom of the pit should be leveled to accommodate future development. Scrap metal should be properly disposed of.

2338-1 North of Abbott, east of Birch. - The pit has been adequately restored.

2438-1 North of Abbott, east of Birch. - The pit has been developed.

2532-1 North of O'Malley, between Old & New Seward Hwy. - This area requires clean up, for visual aesthetics.

2533-1 Lake Otis Parkway (between O'Malley & Abbott) (40 acres) - This land is slated for residential development. Proper disposal of metal and other refuse is needed.

2533-2 Lake Otis Parkway (NW corner of O'Malley) (10 acres) - Minor erosion is taking place. Properr restoration of all slopes is recommended.

2534-1 Lake Otis Parkway (northeast corner of O'Malley) (15 acres) - This pit has been adequately restored. Further, it is part of the proposed Section 16 park.

2631-1 Anchorage S&G (Klatt Rd.) (20 acres) - Traffic circulation at Klatt Road and the Old Seward Highway is very poor. A traffic signal would alleviate the problem.

2631-2 Old Seward Highway (west of O'Malley) (20 acres) - Screening along the buffer strip fronting the Old Seward Highway is recommended for aesthetic purposes.

2634-1 Pioneer S & G (Cange St. and Klatt Rd.) (80 acres) - Dust control along Lake Otis and Cange Street is needed.

2937-1 Rabbit Creek Floodplain at DeArmoun Road - Natural stream recharge has adequately restored the site.

Turnagain Arm

TA-1 Indian Creek (5 acres) - Mining would present environmental concerns. There is presently no activity, and future mining is discouraged.

TA-2 Seward Hwy. (north side, east of Bird Creek) (11.5 acres) - The abandoning of this site as a storage yard for Seward Highway improvements should include proper disposal of all refuse.

TA-3 Seward Hwy. (north side, east of Bird Creek) (2.5 acres) - This pit shall be restored according to the approved restoration plan.

TA-4 Seward Hwy. (MP-98) (135 acres) - This site was previously mined and, as a result, presents slope stability problems and visual impact. Future mining is therefore not recommended.

TA-5 Glacier Creek (100 acres) - Screening along the left bank (looking downstream) would reduce the dust, noise, and visual problems associated with the site. Strict adherence to floodplain mining guidelines would preserve fish habitat.

TA-6 Girdwood (0.5 mi. east and 0.25 mi. south of Seward Hwy.) (15 acres) - This pit presents no problems requiring mitigation. It is well maintained and not visible from roads or residential areas.

TA-7 Portage Creek (5 acres) - This site was investigated as a potential source, and is not recommended for future use due to inaccessibility, visual impacts, and slope instability.

TA-8 Bird Point (10 acres) - Same as TA-7.

TA-9 Seward Hwy. (MP-92) (15 acres) - Same as TA-7.

TA-10 Peterson Creek (15 acres) - Same as TA-4.

TA-11 Seward Hwy. (MP-81.8) (10 acres) - Same as TA-4.

TA-12 Placer River - Same as TA-7.

Eagle River/Eklutna

ER-1 Artillery Rd. and Glenn Hwy. - The mining of this site would bring it down to surrounding grade, thereby increasing its utility. Presently, no mitigative measures are required.

ER-2 N. Birchwood Loop and Beverly Dr. (5 acres) - Steep slopes on northern boundary need to be stabilized. On-site stockpiles of overburden and trees should be properly disposed of.

ER-3 Moose Horn Bus Garage - This site has been adequately restored.

ER-4 Klondike (Old Glenn Hwy.) (100 acres) - This site constitutes a major industrial area along the Old Seward Highway. Screening adjacent to residential areas has been provided. Continued operation is recommended, as prescribed in the mining plans. Mining of the buffer between ER-5 and ER-6 is also recommended.

ER-5 Old Glenn Hwy. at Little Peters Creek (Stephan & Sons) - Same as ER-4.

ER-6 Old Glenn Hwy. at Little Peters Creek (Northern Steel) (40 acres) - Same as ER-4.

ER-7 Old Glenn Hwy. (Central Paving Prod.), Chugiak (40 acres) - Same as ER-4.

ER-8 Izaak Walton Recreation Park - Present mining activities do not present environmental concerns because of its remote location and size of operation. Operations will be complete this year.

ER-9 Eklutna Rv. Floodplain - Continued mining is recommended, with strict compliance to floodplain mining guidelines.

ER-10 Alaska Railroad Reserves - The shallow excavation and the remoteness of the site do not present any problems. Continued mining is recommended.

ER-11 Adjacent to Glenn Hwy; near Bartlett High School - The site is well screened and poses no problems which require correciton.

ER-12 Arctic Valley Road - The pit is well maintained and requires no mitigation.

ER-13 Adjacent to weigh station, west side of Glenn Highway - The pit has been adequately restored.

ER-14 North side of Hiland Drive - The site has been used as a dump, despite signs. Installation of a gate will assist in preventing future dumping.

ER-15 . North side of Eagle River Loop - Minor dumping has taken place at the northern portion of the site. It has no other problems requiring mitigation.

ER-16 Adjacent to Old Glenn Hwy., north of Eagle River - Limited mining activity at this site, along with Old Glenn Highway improvements which encroach on the site, preclude the need for mitigation.

ER-17 Adjacent to Old Glenn Highway - Steep slopes need to be stabilized.

ER-18 North and south of access road between Old & New Glenn Highways - The access road dividing these previously mined areas required a 50-foot cut to meet the grade of the Glenn Highway. Consequently, these pits are not visible; nor are there any safety or other environmental problems associated with them.

ER-19 South of Mirror Lake - The pit has been adequately restored.

Sand Lake

SL-1 MIL Pit - Steep slopes along west and south boundaries; owner plans to develop.

SL-2 Sand Lake Aggregate - Steep slopes inside pit, especially along Lucy Street, however that area is currently being filled to a 2:1 slope; owner plans to develop.

SL-3 Irvin Evenson - Northern portion of pit not yet mined; southern portion mined to approximately 50-75 feet below natural grade.

SL-4 Sky Hills Pit - Owner plans to develop.

SL-5 Susky Pit - Owner plans to develop.

SL-6 Seaview Pit - Owner plans to develop.

SL-7 Harold Wright/Rogers and Babler - Slopes being stabilized; owner plans to develop.

SL-8 Anchorage S& G - Slopes being stabilized; no plans for development as of now.

SL-9 Stephan and Son - Northern portion slopes stabilized; owner plans to develop; southern portion has been filled.

SL-10 RCJ Pit - Slopes stable; no plans for development as of now.

NOTE: See Report #2 - Sand Lake Area Comprehensive Development Plan, which is a separate report, for further discussion on the impacts and recommendations for this area.

C. CONCLUSION

Based upon those factors evaluated in the Area Assessment Matrices contained in Appendix J and the general environmental status of each extraction site, it is our opinion that existing mining activities do not constitute a major action significantly affecting the environment.

As presented in the Environmental Synopsis, there are mitigating measures at each location which, if implemented, would make the sites more acceptable from an environmental standpoint such as screening with landscaping, fencing, etc. We recommend these measures be instituted.

In some areas safety hazards exist. These are mainly in the areas of steep, unprotected slopes, lack of guard rails along roadways, and the lack of adequate perimeter fencing to exclude unauthorized personnel.

At none of the locations visited was there evidence of the potential for major (or minor) fish kills, contamination of groundwater from pollutants, stream siltation, or health hazards to on-site workers or to the surrounding neighborhood. The potential for a catastrophic environmental impact does not exist.

From a Municipal management position, the problems of dust, noise and traffic congestion are controllable environmental factors and can be mitigated with implementation of procedures affecting the operation of each facility or the strict enforcement of existing ordinances and controls.

III ANALYTICAL EVALUATIONS

A. PROJECTED SAND AND GRAVEL DEMAND

Introduction

For purposes of this report, we have used the projected population growth of the Municipality of Anchorage to the year 2000 as a basis for determining future sand and gravel demand for housing. By using the Comprehensive Plan Revision Technical Report entitled, Commercial-Industrial Employment and Acreage Allocations: Year 2000, published in February 1981 by the Municipality Planning Department, we were able to project the required additional land to be developed for commercial and industrial uses.

In addition to housing, commercial and industrial development, it is necessary to account for the sand and gravel consumption of the public sector. This was done by obtaining from the Municipality the projected Capital Improvements Program (C.I.P.) through the year 1987. Future projections through the year 2000 for sand and gravel were extrapolated from the CIP program based upon the population growth.

Population projections (Table III.1) were obtained from the Municipal Planning Department. As noted later in this report, the year 2000 projected population was revised downward from the original estimate of 337,765 made in 1980 to an estimate of 318,336 made in 1982.

Of the 318,336 persons in the Municipality of Anchorage by the year 2000, it is projected that 18,000 will be military personnel. Housing required for military personnel living off-base is included in the housing demand.

The object of Section III.A is to provide an engineering estimate of the total sand and gravel demand on a yearly basis, through the year 2000, within the Municipality of Anchorage.

In the future, we recommend, as a condition of approval of any Conditional Use Permit for natural resource (gravel) extraction, that accurate, verified production quantities be

TABLE III.1. MUNICIPALITY OF ANCHORAGE POPULATION PROJECTIONS TO YEAR 2000

Year	Eagle River	Anchorage	Municipality Population Total	Annual % Growth	Cumulative % Growth
1980	12,858	161,573	174,431	3.1	
1981	14,458	165,365	179,823	2.0	3.1
1982	16,058	167,394	183,452	4.7	5.1
1983	17,658	174,404	192,062	8.8	9.8
1984	19,258	189,717	208,975	10.8	18.6
1985	20,850	210,637	231,487	4.3	29.4
1986	21,974	219,438	241,412	0.1	33.7
1987	23,098	218,438	241,536	0.3	33.8
1988	24,222	217,987	242,209	0.9	34.1
1989	25,346	219,099	244,445	1.3	35.0
1990	26,470	221,192	247,662	1.6	36.3
1991	28,623	223,113	251,736	2.2	37.9
1992	30,776	226,580	257,356	2.3	40.1
1993	32,929	230,435	263,364	2.1	42.4
1994	35,082	233,633	268,715	2.5	44.5
1995	37,235	238,189	275,424	2.9	47.0
1996	39,388	244,100	283,488	3.3	49.9
1997	41,541	251,252	292,793	3.1	53.2
1998	43,694	258,160	301,854	2.5	56.3
1999	45,847	263,701	309,548	2.8	58.8
2000	48,000	270,336	318,336		61.6

submitted on a yearly basis to the Municipality of Anchorage. This information will then provide the Municipal staff with accurate statistical data which can be utilized to update the findings of this report.

Housing Demand for Sand and Gravel

Prior to computing the housing demand for sand and gravel, it was necessary to determine the basis for which housing increases could be projected. Table III.2 projects the yearly increases in both single family (S.F.) and multi-family (M.F.) dwelling units, by year, through the year 2000.

The February 1981 study by the Municipality Planning Department, referred to in the introduction to this section, found the 1980 housing stock to be comprised of 33,097 (55.4%) single family dwelling units and 26,633 (44.6%) multi-family dwelling units.

The Municipality Planning staff projected a housing stock increase within the Municipality to a total of 71,785 dwelling units, based upon the year 2000 population of 337,765. However, the total population estimate was reduced in 1982 to 318,336 people by the year 2000. Reducing the total population estimate caused a reduction in the estimated total dwelling units. As shown on Table III.2, the estimated increase in single family dwelling units is 19,979, and estimated increase in multi-family dwelling units is 32,918 from 1983 to 2000.

Table III.2 assumes that 40.44% of the increase in population will live in single family homes and that 59.56% of the increase in population will live in multi-family homes. This assumption relies on trends in Municipality of Anchorage studies and the fact that higher density housing is becoming an economic necessity. The February 1981 study found that 2.73 people (on the average) were living in each single family residence and 2.44 people (on the average) were living in each multi-family unit. Using the combined data from above the increase in dwelling units, by single family and multi-family category, was projected, by year, to the year 2000.

After computing the estimated housing demand, by dwelling units, the next step was to determine the required sand and gravel quantities for single family, multi-family,

TABLE III.2. HOUSING DEMAND

Year	Population Increase	S.F. @ 40.44%	M.F. @ 59.56%	Increase in Dwelling Units S.F. @ 2.73 P/DU	M.F. @ 2.44 P/DU	Total
1981	5,392					
1982	3,629					
1983	8,610	3,481	5,129	1,275	2,102	3,377
1984	16,913	6,840	10,073	2,505	4,128	6,633
1985	22,512	9,104	13,408	3,335	5,495	8,830
1986	9,925	4,014	5,911	1,470	2,422	3,892
1987	124	50	74	18	30	48
1988	673	272	401	100	164	264
1989	2,236	904	1,332	331	542	873
1990	3,217	1,300	1,917	476	785	1,261
1991	4,074	1,647	2,427	603	995	1,598
1992	5,620	2,273	3,347	833	1,372	2,205
1993	6,008	2,430	3,578	890	1,466	2,356
1994	5,351	2,164	3,187	793	1,306	2,099
1995	6,709	2,713	3,996	994	1,637	2,631
1996	8,064	3,261	4,803	1,194	1,968	3,162
1997	9,305	3,763	5,542	1,378	2,271	3,649
1998	9,061	3,664	5,397	1,342	2,212	3,554
1999	7,694	3,111	4,583	1,140	1,878	3,018
2000	8,788	3,554	5,234	1,302	2,145	3,447
Total	143,905	54,547	80,337	19,979	32,918	52,897

commercial and industrial development. In residential development, the majority of gravel is utilized in the construction of streets (public and private) and extensions to existing public utilities, including water mains, sanitary sewers and storm sewers. Commercial and industrial development require substantial amounts of sand and gravel in the construction of asphalt parking areas as well as in concrete and other building materials.

The amount of material used in the construction of streets, parking areas, building foundations and utilities varies directly with the soils condition. Design and construction criteria have been established by the Department of Public Works and the various utility companies. These criteria were utilized to estimate the amounts of sand and gravel required for construction purposes. Therefore, all demand estimates are based on current design criteria.

Sand and gravel consumption is determined by land use (zoning), soils design criteria and construction requirements. In order to project the future consumption of sand and gravel, it was necessary to know: a) the projected population growth; b) the zoning categories; c) the amount of undeveloped land in each zoning category; d) the estimated development; and e) the soils characteristics of the property most likely to be developed.

Within the Municipality, the single family zoning categories are R-1, R-1A, R-1SL, R-2A, R-6, R-7, R-8 and R-9. The multi-family zoning categories are R-2, D-2, R-2SL, R-3, D-3, R-3SL, R-4 and R-5. Using the zoning sheets and aerial photographs, it was possible to planimeter the existing undeveloped areas in order to obtain the undeveloped acreages of each zoning category. Those values are shown, together with additional information on Tables A-1.1 to A-1.10, entitled ESTIMATED SAND AND GRAVEL USE, PRIVATE DEVELOPMENT, in Appendix I.

In addition to estimating total sand and gravel consumption for residential, commercial and industrial development, it is also necessary to estimate the volume of gravel required for the construction of roads, utilities, buildings, parking lots, building pads and driveways. This was done by the use of Land Use Coverage Multipliers (LUCM). LUCM values obtained for each zoning category are listed in Table III.3. Application of the LUCM are explained, together with the necessary equations in the footnotes to Table A-1.11 in Appendix I.

TABLE III.3. LAND USE COVERAGE MULTIPLIERS

Zoning	Road Area Multiplier (%)	Buildings, Parking Lots, Bldg. Pads & Driveways (%)
R-1/R-1A/R-1SL	28	10-20
R-2/R-2A/R-2D/D-2/R-25SL	24	15
R-3/D-3/R-3SL	24	20-30
R-4	24	20
R-5	24	20
R-6	12	0
R-7	20	15
R-8	4	0
R-9	6	0
R-0	24	40
B-1	20	60
B-2A/B-2B/B-2C	30	60
B-3/B-3SL	20	64
B-4	12	40
I-1/I-2	20	30
I-3*	0	0
U	10	7

* Not shown on current zoning sheets

In order to establish the estimated average depth of street gravel base and on-site gravel requirements, the soils and drainage conditions were determined using available local soils studies in combination with the U.S. Soil Conservation Service Surface Soils Map, and the Anchorage Coastal Resource Atlas. The above data was then incorporated into Tables A-1.1 to A-1.10 in Appendix I.

Additionally, it is necessary to account for the use of concrete and gravel backfill quantities in relationship to the various zoning categories. This data is shown on Tables A-1.12 and A-1.13 in the Appendix and was applied to Columns 12 and 14 of Tables A-1.1 to A-1.10.

Using the Land Use Coverage Multipliers (LUCM) offers an efficient method of estimating sand and gravel consumption when zoning regulations are applied to undeveloped land. Two other alternative methods of estimating sand and gravel consumption were considered. One, the Milage method, whereby only the area required for streets and utilities within a zoning category are estimated did not fulfill the requirements since this method did not consider the effect on sand and gravel consumption outside the public rights-of-way. The second, called the Land Planning Method, based on existing zoning, is more time consuming and considerably more expensive since it is necessary to develop detailed site plans for each zoned parcel.

Due to the large lot areas and based upon aerial photographs for land zoned R-6, R-8 and R-9, it is apparent that purchasers of these lots will be able to construct homes on the most suitable areas of the land without the need for importation of sand and gravel materials. Generally, if materials are needed, they will in most cases come directly from on-site locations.

For future use of this report and to assist the Municipality in refining sand and gravel consumption forecasts, it is recommend that sand and gravel use figures be requested from project owners of specific projects following construction and that the values obtained be applied to both the LUCM for the specific zone and to Tables A-1.1 through A-1.10 in order to verify, re-evaluate, or update the estimated quantities. In our opinion, the method chosen for estimation is appropriate since it offers the staff the ability to follow developments in various zoning categories, gather information and easily modify the projections contained herein.

Table III.4, Housing Demand for Sand and Gravel, lists by year, to 2000, the estimated acres of single family and multi-family development will be required to meet the housing needs of the projected population. The acreages given in Columns 2 and 3 of Table III.4 are a result of dividing Columns 5 and 6; Table III.2 by the average housing density per acre.

Based upon conversations with the Municipal Planning Department staff, it was determined that the average housing density for all single family zones should be in the range of 3 to 5 dwelling units per acre. A density of 4.2 single family dwelling units per acre was determined following a review of recent single family plats. A density of 14.0 multi-family dwelling units per acre was determined following a staff recommendation that a value between 13.0 and 15.0 should be used. Applying the values of 4.2 and 14.0 to the increase in dwelling units on Table III.2 yields the respective acreage requirements on Table III.4.

Incorporating the data developed in Tables A-1.1 to A-1.10, Appendix I, an average requirement of 3,000 cubic yards of gravel was computed for development of an acre of single family zoned property and 4,000 cubic yards for development of an acre of multi-family zoned property. The results of these computations are listed in Columns 4, 5 and 6 of Table III.4.

The final result is that an estimated 23,679,000 cubic yards will be required to satisfy the sand and gravel requirements of the housing industry between 1984 and 2000.

TABLE III.4. HOUSING DEMAND FOR SAND AND GRAVEL

	1	2	3	4	5
Year	Acres of S.F. Dev.	Acres of M.F. Dev.	Gravel Req'd. S.F. Dev. (c.y.)	Gravel Req'd. M.F. Dev. (c.y.)	Total (c.y.)
1981	190	94	570,000	376,000	
1982	128	63	384,000	252,000	
1983	304	150	912,000	600,000	1,512,000
1984	596	295	1,788,000	1,180,000	2,968,000
1985	794	393	2,382,000	1,572,000	3,954,000
1986	350	173	1,050,000	692,000	1,742,000
1987	4	2	12,000	8,000	20,000
1988	24	12	72,000	48,000	120,000
1989	79	39	237,000	156,000	393,000
1990	113	56	339,000	224,000	563,000
1991	144	71	432,000	284,000	716,000
1992	198	98	594,000	392,000	986,000
1993	212	105	636,000	420,000	1,056,000
1994	189	93	567,000	372,000	939,000
1995	237	117	711,000	468,000	1,179,000
1996	284	141	852,000	564,000	1,416,000
1997	328	162	984,000	648,000	1,632,000
1998	320	158	960,000	632,000	1,592,000
1999	271	134	813,000	536,000	1,239,000
2000	310	153	930,000	612,000	1,542,000
Total	5,075	2,409	15,225,000	10,036,000	23,679,000

Note: Use 3,000 c.y. per acre for single family development and 4,000 c.y. per acre for multi-family development.

Density Avg. = 4.2 dwelling units per single family developed acre
= 14.0 dwelling units per multi-family developed acre

Commercial and Industrial Development Demand for Sand and Gravel

In February 1981 the Municipality Planning Department issued a Comprehensive Plan Revision Technical Report entitled, "Commercial-Industrial Employment and Acreage Allocations: Year 2000". This technical report was based in large part on the inventory of development and vacant land in August 1980 and proceeds to the employment and acreage allocations in the year 2000 by using the statistical methods of multiple linear regression for future industrial land requirements with the future split being based on the current relationships between these two sectors.

According to this technical report, in 1980, there was 1,423.5 acres of industrial property being utilized while the projected use in the year 2000 was a total of 2,025.1 acres. This means a net increase of 601.6 acres is projected to be developed as future industrial property.

Commercial property was analyzed in a somewhat different fashion by assuming a portion of all future developed commercial property will be "redeveloped": "Much of the commercial land that now exists in the Anchorage Bowl, especially along arterials and within portions of the Downtown, is under-utilized and can be expected to redevelop to higher densities over the next 20 to 25 years." The analysis of the commercial land required in the year 2000, including the land to be redeveloped, resulted in the following statistics:

319.9	acres to be designated commercial
398.2	acres to be redeveloped
38.8	acres required to be rezoned to commercial
756.9	acres of commercial land to be developed by 2000

The above acreage requirements were confirmed with the Planning Staff prior to the generation of Table III.5. Table III.5 lists, on a yearly basis, the sand and gravel demand for commercial and industrial development. The yearly acreage requirements were allocated based on the percentage of the population growth for that particular year.

Using Tables A-1.1 to A-1.10, Appendix I, it was calculated that development of a single acre of commercial land requires an average of 5,195 cubic yards of sand and gravel while

TABLE III.5. COMMERCIAL AND INDUSTRIAL DEMAND FOR SAND AND GRAVEL

Year	% Pop. Increase	Comm. Develop. (acres)	Indust. Develop. (acres)	Gravel Comm. (c.y.)	Gravel Indust. (c.y.)	Total (c.y.)
1981	3.7469	28.36	22.56			
1982	2.5219	19.09	15.18			
1983	5.9833	45.29	36.02	235,281	169,654	404,935
1984	11.7550	88.98	70.77	462,251	333,327	795,578
1985	15.6450	118.43	94.18	615,243	443,588	1,058,831
1986	6.8969	52.21	41.52	271.230	195,559	466,789
1987	0.0864	0.65	0.52	3,376	2,449	5,825
1988	0.4678	3.54	2.82	18,390	13,282	31,672
1989	1.5538	11.76	9.35	61,093	44,038	105,131
1990	2.2355	16.93	13.46	87.951	63,397	151,348
1991	2.8310	21.43	17.04	111,328	80,258	191,586
1992	3.9055	29.56	23.51	153,564	110,732	264,296
1993	4.1750	31.60	25.13	164,162	118,362	282,524
1994	3.7185	28.15	22.39	146,239	105,457	251,696
1995	4.6622	35.29	28.07	183,331	132,209	315,540
1996	5.6038	42.42	33.73	220,372	158,868	379,240
1997	6.4662	48.95	38.92	254,295	183,313	437,608
1998	6.2966	47.67	37.90	247,646	178,509	426,155
1999	5.3466	40.46	32.18	210,189	151,568	361,757
2000	6.1068	46.23	36.75	240,165	173,093	413,258
TOTAL	100.0000	757.00	602.00	3,686,106	2,657,663	6,343,769

NOTE: Use 5,195 c.y. per acre of commercial development and 4,710 c.y. per acre of industrial development.

one acre of industrial development requires 4,710 cubic yards. Using the above data, the projected total sand and gravel demand for commercial and industrial development from 1983 through the year 2000 is estimated to be a total of 6,343,769 cubic yards.

Demand for Sand and Gravel by Public Projects

The Department of Public Works was contacted in order to establish the volumes of sand and gravel which could be estimated for future public streets, public water and sewer projects, and miscellaneous public projects. Tables III.6, III.7 and III.8 were developed based upon this information. Also considered was the volume of material required for maintenance and sanding purposes.

As with all the demand calculations, yearly totals are a result of projecting the future requirements for sand and gravel based upon the population increases within the Municipality.

Table III.9 totals the Public Projects estimated demand at 10,943,149 cubic yards, while the total projected requirement for Maintenance purposes is 1,420,057 cubic yards to the year 2000.

TABLE III.6. GRAVEL REQUIRED FOR FUTURE PUBLIC STREET PROJECTS

Project	Projected Const.	Feet of Improvements	Amt. Gravel For Roads (c.y.)
Turpin - DeBar to Glenn Hwy.	1982	5,193	26,444
Strawberry-Jewel Lake Rd. to Arlene	1984	3,650	20,080
Wisconsin-Northern Lts.-43rd Ct.	1983-1984	6,155	32,712
Arctic Blvd.-Int'l. to Dimond	1982-1984	10,540	64,411
Patterson-N. Lts. Blvd. to Tudor	1984	5,520	38,180
Baxter-Tudor to 16th Ave.	1984	9,000	20,750
Northwood Dr.-88th to Dimond Blvd.	1983	1,500	11,483
Merril Field Dr.,Airport Hts. to 15th Ave.	1983	3,050	10,166
E. 6th Ave.-Pine St. to E. Boundary of Mellowood Subdivision	1984	1,300	4,333
Patterson-DeBarr to E. 6th		2,650	12,513
36th Ave.-Arctic to Spenard	1983	1,930	11,804
Denali St.-36th Ave. to 39th Ave.	1983	900	6,417
16th Ave.-"C" to Gambell	1983	2,000	8,922
Artillery Rd.-Glenn Hwy. to Sewage Treatment Plant	1983	5,400	4,800
3rd Ave. Elmendorf Access to Post Rd.	1983	7,100	5,000
Old Seward	1982	8,500	30,000
Arctic - Tudor - Int.	1982	4,225	18,000
Bike Trails			22,000
Bragaw St., Abbott Rd. to O'Malley Rd.	1984	5,300	15,017
Northwood Dr.-Strawberry to Raspberry	1983	2,650	61,539
Cranberry St.,Collins Way-Raspberry	1987	1,400	10,578
Denali St.-39th Ave. to Tudor Rd.	1984	1,775	13,115
E. 6th Ave.-Patterson to Cherry St.	1985	4,625	18,500
Collins Way-Jewell Lk. Rd. to 64th	1985	1,550	6,200
Strawberry-Arlene to Northwood Dr.	1985	1,300	9,606
Lk. Otis Pkwy-O'Malley Rd. to Abbott	1985	5,300	44,756
100th Ave.-Victor Rd. to Camden Bay Dr.	1986	3,300	38,317
Lk. Otis Pkwy-O'Malley to Huffmand	1987	5,300	33,567
Huffman Rd.-Timberlane Dr. to Old Seward Highway	1984	5,100	57,139
40th Ave., Old Seward Hwy. to "C" St.	1987	3,250	48,028
Timberlane Dr.,Klatt Rd.-Huffman Rd.	1987	2,650	30,033
Northwood Dr.,Spendar Rd. to Int'l. Airport Rd.	1987	3,800	24,067
Raspberry Rd.-"C" St. to Intersection w/DOT Improve.	1986	3,340	31,730
Total			799,621

TABLE III.7. GRAVEL REQUIRED FOR PUBLIC SEWER AND WATER PROJECTS

Project	Projected Const.	Feet of Improvements	Amt. Gravel for Proposed Sewers(c.y.)
Sherwood Acres Phase III	1983	2,500	3,240
Old Seward Trunk	1983	5,000	10,185
West Dimond Trunk	1984	5,000	18,888
Montaque Manor System	1983	1,500	1,944
Little Tree Extended	1984	2,700	3,000
East Oceanview Storm	1984	2,000	888
	1983	1,500	1,388
East Dimond Trunk	1984	2,500	4,167
Newland Storm	1986	3,500	666
Pleasant Valley Kobuk Storm	1985	6,950	8,880
St. Gotthard Storm Drain	1987	1,150	1,278
Thunderbird Storm Drain	1987	1,400	1,536
Wesleyen-Mills-Glacier St. Storm	1986	1,350	600
S. Glenn Hwy. Oklahoma to Boniface St., Phase I	1984	2,500	1,111
Roosevelt Park Storm	1983	2,500	1,111
Indust. Pk. Int'l. to 36th Storm	1985	4,000	4,444
Northwood Storm System Extension	1983-1984	2,650	2,355
Creekside School - 6th Ave. to Old Harbor Storm	1983	5,600	4,978
			70,659

Project	Projected Const.	Feet of Improvement	Amt. Gravel for Water (c.y.)
72nd Ave./Hyatt to Lake Otis	1986	1,700	3,463
40th Ave./"C" St. to Denali	1987	2,000	4,074
Denali Sto./40th Ave. to Tudor	1987	1,400	2,593
Abbott Loop/Tudor to Abbot Rd.	1982-1985	15,700	31,981*
Chugach Way/Arctic Blvd.-Spenard Rd.	1983	1,800	3,333
Abbott Rd./Abbott Loop - Lk. Otis	1983	5,300	10,796
4th Ave./Gambell to "E" St.	1983-1984	3,600	10,000
Debarr/Airport Hts. to Sitka	1984	3,400	9,388
A Street/Tudor to Int'l Airport Rd.	1984	2,700	5,500
4th Ave./"E" St. to "I" St.	1985	1,500	3,611
Lore Rd./Lk. Otis to Abbott	1986	7,900	16,093
Spruce St./Lore Rd. to 68th Ave.	1986	2,650	5,398
Bragraw St./Providence to Tudor	1979	1,300	2,888**
68th Ave./Lk. Otis to Abbott Loop Rd.	1980	5,300	10,796**
Dowling Rd./Pederson-N.Seward Hwy.	1981	3,900	7,945**
Anticipated WID's	1982	10,000	20,370**
	1983	10,000	20,370
	1984	10,000	20,370
	1985	10,000	20,370
	1986	10,000	20,370
	1987	10,000	20,370
			200,084
Total			270,743

* = 1982 Deleted from Total
** = Not Included in Total

TABLE III.8. GRAVEL REQUIRED FOR MISCELLANEOUS PUBLIC PROJECTS

Project	Projected Const.	Feet of Improvements	Amt. Gravel Sewers(c.y.)
LID 85 Zodial Manor	1979		1,815**
LID 86 Campbell Heights North	1980		7,778**
Fire Lake Interceptor	1982	5,280	4,778**
North Valley Trunk	1982	5,280	5,867**
Abbott Loop Road Trunk	1982	900	3,333**
S.E. Interceptor, E-2 to O'Malley	1982	7,500	23,611**
CBD-1 Trunk	1979	3,000	10,000**
CBD-2 Trunk	1979	4,500	16,667**
R&R Fish Creek Int.	1983	1,300	8,000
R&R Tidal Flats Knik	1983	5,805	12,900
R&R Public Works	Unknown (1985)	19,000	15,000
R&R Int'l. Airport	1982	5,000	6,000**
R&R C-9 Trunk	1982	1,000	1,500**
Windomere Scenic Park	1984	1,850	4,000
Anticipated LID's	1982	30,000	33,333**
	1983	40,000	44,444
	1984	42,000	47,778
	1985	45,000	50,000
	1986	47,000	52,222
	1987	47,000	52,222
Campbell Street Trunk	1982-1983	3,000	8,704*
C-3 Trunk - North	1983	2,640	3,556
Southeast Interceptor	1983-1984	7,200	33,185
C-5-2 Trunk, Phase II	1983	3,960	13,333
78-Inch West Interceptor (Phase II)	1983-1984	6,000	36,667
Southeast Interceptor	1984	1,500	9,167
North Valley Trunk	1985	10,560	31,481
C-6 Trunk	1986	7,920	28,889
C-7 Trunk	1987	7,920	34,667
Rabbit Creek Pump Station	1985		16,667
Total			480,195

* = 1982 Deleted from Total
** = Not Included in Total

TABLE III.9. PUBLIC PROJECTS AND MAINTENANCE DEMAND FOR SAND AND GRAVEL

Year	% Population Increase	Public Projects (c.y.)	Maintenance (c.y.)
1983	5.9833	379,200	49,209
1984	11.755	423,774	54,993
1985	15.645	490,073	63,596
1986	6.8969	523,872	67,982
1987	0.0864	524,324	68,040
1988	0.4678	526,775	68,358
1989	1.5538	534,961	69,420
1990	2.2355	546,920	70,972
1991	2.8310	562,403	72,981
1992	3.9055	584,368	75,831
1993	4.1750	608,765	78,997
1994	3.7185	631,402	81,935
1995	4.6622	660,839	85,754
1996	5.6038	697,871	90,560
1997	6.4662	742,997	96,416
1998	6.2966	789,781	102,487
1999	5.3466	832,007	107,966
2000	6.1068	882,816	114,560
TOTAL	100.0000	10,943,149	1,420,057

Demand Summary

Housing	23,679,000	cubic yards
Commercial & Industrial	6,343,769	cubic yards
Public Projects	10,943,149	cubic yards
Maintenance	1,420,057	cubic yards
Total	42,385,975	cubic yards

The total sand and gravel demand of 42,385,975 cubic yards required from 1983 to the year 2000 includes all residential (housing), commercial, industrial, public projects and maintenance uses which can be estimated. Not included in this total demand are the requirements of the Alaska Department of Transportation, the Port of Anchorage or other entities within the Municipality of Anchorage which may have future projects requiring large quantities of sand and gravel.

It is beyond the scope of this report to search out and analyze every potential project which might be constructed in the future. However, if a large project, such as expansion of the Port of Anchorage at Ship Creek, were undertaken, sand and gravel would be at a premium in the Anchorage Bowl. Our projections, indicate that supply will not meet the demand in the foreseeable future without either decreasing demand or increasing the supply of material. (see Section III.B, Projected Supply Availability)

Included in Appendix C is a memorandum obtained from the State of Alaska regarding the gravel needs of the Department of Transportation through the year 1987. Their demand, in excess of 500,000 cubic yards per year, is anticipated to be mined from existing airport materials sites. These materials will probably be removed from the existing site (#2018-1) at the west end of the east-west runway. Should this site become depleted sooner than expected, an additional burden of 500,000 cubic yards per year on the existing sites may create an intolerable shortage of sand and gravel.

Table III.10 summarizes the projected sand and gravel demand, by year, from 1983 to 2000. Based upon the projected population growth of the Municipality of Anchorage, demand will increase steadily from 1983 through 1985 when the peak demand will be in excess of 5,500,000 cubic yards. Demand then recedes until a low is reached in 1987 of 618,189 cubic

TABLE III.10. SUMMARY OF SAND AND GRAVEL DEMAND - 1983-2000, IN CUBIC YARDS

Year	S.F. Develop.	M.F. Develop.	Commercial Industrial	Public Projects	Maint.	Total
1983	912,000	600,000	404,935	379,200	49,209	2,345,344
1984	1,788,000	1,180,000	795,578	423,774	54,993	4,242,345
1985	2,382,000	1,572,000	1,058,831	490,073	63,596	5,566,500
1986	1,050,000	692,000	466,789	523,872	67,982	2,800,643
1987	12,000	8,000	5,825	524,324	68,040	618,189
1988	72,000	48,000	31,672	526,775	68,358	746,805
1989	237,000	156,000	105,131	534,961	69,420	1,102,512
1990	339,000	224,000	151,348	546,920	70,972	1,221,240
1991	432,000	284,000	191,586	562,403	72,981	1,542,970
1992	594,000	392,000	264,296	584,368	75,831	1,910,495
1993	636,000	420,000	282,524	608,765	78,997	2,026,286
1994	567,000	372,000	251,696	631,402	81,935	1,904,033
1995	711,000	468,000	315,540	660,839	85,754	2,241,133
1996	852,000	564,000	379,240	697,871	90,560	2,583,671
1997	984,000	648,000	437,608	742,997	96,416	2,909,021
1998	960,000	632,000	426,155	789,781	102,487	2,910,423
1999	813,000	536,000	361,757	832,007	107,996	2,630,760
2000	930,000	612,000	413,528	882,816	114,560	2,952,904
	14,271,000	9,408,000	6,344,039	10,943,148	1,420,087	42,386,245

yards. From 1988 until the year 2000, demand is generally increasing each year. This corresponds directly to the population growth in the Municipality.

B. PROJECTED SUPPLY AVAILABILITY

Introduction

In Section III.A, it was calculated that the total demand within the Municipality of Anchorage would be approximately 42,400,000 cubic yards of sand and gravel between the years 1983 and the year 2000.

To assess whether supply can meet the projected demand on a yearly basis, it was necessary to determine the existing reserves within each mining site. In most cases the information on the available reserves was obtained from the site operations. Values used may be optimistic or pessimistic depending on a variety of factors.

It is our opinion that there has not been sufficient core borings or drill holes placed, in most extraction sites, to know with certainty the remaining reserves. However, it was beyond the scope of our responsibility to field verify the reserves. The values given for each mining site are a best estimate.

A major factor in the assessment of supply available is the unknown Municipal determination with regard to the Sand Lake pits. If the Sand Lake pits are closed as of December 31, 1982, then other existing sources of supply must be expanded to make up for this supply source being removed.

Many experts consider Cook Inlet from Fire Island to Matanuska-Susitna Borough boundaries to be the best potential renewable source of sand and gravel in the Anchorage Bowl. The information available at present is limited to data gathered for special purposes such as the electric cable crossings for Chugach Electric Association, bottom sampling for dredging purposes taken by the Army Corps of Engineers, and the subsurface exploration program for the Knik Arm bridge crossing. No special studies have been conducted in conjunction with this study to determine the quality of sand and gravel or the potential recharge rates. Offshore mining for sand and gravel in Cook Inlet does appear to be a reasonable alternative source.

Estimated Minable Reserves

As indicated by Table III.11, the estimated total volume of minable reserves of sand and gravel is 19,835,000 cubic yards within the study area. An additional 21,250,000 cubic yards can be anticipated via the Alaska Railroad for a total of 41,085,500 cubic yards. This is a maximum estimate assuming eventual total depletion of known reserves by the year 2000.

The two largest contributing reserve areas shown are ER-9, Eklutna River floodplain at 3,600,000 cubic yards, and TA-5, Glacier Creek at 6,500,000 cubic yards. ER-9 is owned by Eklutna, Inc., and TA-5 is owned by the State of Alaska. Both of these values represent our best engineering estimate of the quantities which might become available, if developed to their full potential. Potential problems with continued operations at ER-10 relative to the Native Land Settlement Act, have been discussed in Section II.4. Section III.F discusses in detail the recharge capabilities of both the Eklutna River and the Glacier Creek floodplain.

It should be noted that TA-5, Glacier Creek, has been assumed to contribute 3,500,000 cubic yards of material to the 17-Year Supply total. This is an average yearly production volume of 206,000 cubic yards. Production on these levels is possible but only with major capital expenditure of funds by an operator. Either the railroad must be extended to the mining site or the material from the site must be brought to the railroad by conveyor. In either case, stockpiles and loading facilities must be constructed to handle such large quantities of sand and gravel. Other problems such as the availability of gravel-hauling railcars, track time to transport material to Anchorage, a location for off-loading the cars, all enter into the economic analysis regarding this site. Notwithstanding the question of recharge the estimate of material available from TA-5 is optimistic.

Using TA-5 as only one example, it is recommended that the value of 30,000,000 cubic yards of on-shore minable reserves be used for estimating purposes. This is a conservative (low) estimate, but it does assume that at least a portion of the questionable sources (such as ER-9, ER-10, and TA-5) become productive and contribute to the supply side of the supply vs. demand equation. At some point, based upon economic parameters (i.e., the sales price of gravel) an operator will exploit the existing resources. Whether this development will take place prior to a severe shortage of supply is unknown and is beyond the scope of this report.

TABLE III.11. ESTIMATED MINABLE RESERVES

(in cubic yards)

Material Site	Estimated Reserves Low	High	17-Year Supply
1233-1	53,000	53,000	53,000
2634-1	1,500,000	2,500,000	1,500,000
TA-1	0	5,000	0
TA-2	15,000	23,000	23,000
TA-3	30,000	40,000	35,000
TA-5	272,000	6,500,000	3,500,000
ER-1	800,000	1,000,000	900,000
ER-3	100,000	260,000	100,000
ER-4	200,000	260,000	200,000
ER-5	250,000	250,000	250,000
ER-6	500,000	750,000	600,000
ER-7	500,000	750,000	600,000
ER-8	20,000	40,000	30,000
ER-9	0	3,600,000	1,200,000
ER-10	0	1,500,000	500,000
SL-1	0	132,000	100,000
SL-2	500,000	1,780,000	900,000
SL-3	400,000	800,000	700,000
SL-6	0	50,000	40,000
SL-7	50,000	80,000	50,000
SL-9	100,000	160,000	80,000
SL-10	0	42,000	40,000
SL-11	160,000	260,000	200,000
	5,450,000	19,835,000	11,601,000
Alaska R.R.	21,250,000	21,250,000	21,250,000
Total	26,700,000	41,085,000	32,851,000

As discussed in Section II.A, Matanuska Valley sand and gravel supplies are available by importation to Anchorage via the Alaska Railroad. Information gathered from the Alaska Railroad indicates that they have imported gravel to the Anchorage Bowl since 1975 with the volume increasing yearly to a total of 1,197,000 c.y. (2,000,000 tons) in 1981. Trains are brought into Anchorage from mid-April to the end of September. No gravel is brought in during the winter months due to increased wear on the equipment and the extra difficulties encountered during winter mining operations in handling frozen sand and gravel.

At peak capacity, the Alaska Railroad is capable of importing a total of 10,400 c.y. (17,300 tons) per day on three trains operating five days (occasionally six days) per week. Total importation to Anchorage for 1982 will be approximately 2,600,000 tons or 1,550,000 cubic yards.

The Alaska Railroad has indicated that the Palmer/Mat-Su gravel operators have inquired about the possibility of purchasing 80 privately owned gravel hauling cars and incorporating this new rolling stock with that owned by the railroad. There is not a time schedule proposed for the purchase of these new cars. <u>If</u> 80 new cars are added, Alaska Railroad has indicated that new engines would not be required. An increased supply of approximately 380,000 cubic yards per year would result by the addition of these new cars.

Since there is not a timetable for additional new rolling stock, it is our opinion that this additional production should <u>not</u> be assumed as a part of the yearly imported supply.

For purposes of this study, importation of material from the Matanuska Valley is considered a part of the overall supply and 1,250,000 cubic yards average per year have been added to Table III.11.

<u>Supply Summary</u>

Table III.11 indicates a 17-year supply of 32,851,000 cubic yards. This value assumes development of some questionable sources as discussed in the previous section. Supply is a function of demand and does not depend upon population projections or other assumptions. As mentioned in Section III.B, assuming a value of 30,000,000 cubic yards as the minable reserves to the year 2000 is reasonable based upon known data.

C. INTEGRATED PRODUCTION LEVELS

The purpose of this section is: 1) project and monitor integrated production of sand and gravel based on projected demand, as shown on Table III.10, over a 17-year period; and 2) analyze the levels of deficit which must be supplied by importing materials from Palmer-Matanuska Valley, development of additional sources or achieving a reduction in the demand. The intent of this analysis is to present a simple procedure for the study and re-evaluation of supply-demand conditions for sand and gravel materials.

Production levels at various sources are based on inventory and impact analysis. The criteria used in establishing production levels include haulage distance, local mining constraints, expedient mining in some areas, and mining limitations due to hours of operation and/or limited access. This method is to some extent subjective because all marketing variables requiring substantial research could not be considered, and business practices of each venture which may create production variations are difficult to predict. It is recommended that the supply-demand projections presented in this report be re-evaluated after detailed mining, grading and operation plans are developed for each pit. These plans, when submitted, should address production levels more accurately. The scope of this study includes preparation of guidelines for the planning and design of mining sites and operations. The Developers Requirements for Natural Resource Extraction addresses the continued operation of existing sites and details necessary to evaluate new proposed operations.

Originally, it was intended to optimize production levels based on cost and haulage distance, using a computer optimization model. A mathematical model was selected for this purpose known as I/O PNET and this program may be used for this purpose in the future. (Refer to Appendix E - IOPNET - Program Description and Access Guide) However, during the course of this study, it was determined that production optimization based on cost and distance alone would be misleading due to many other variables. For instance, expedient mining may be desirable in some areas in the interest of the community shortening the duration of impacts, and realizing long-term planning objectives sooner. This is particularly true in the Sand Lake area. Two of the most difficult aspects in estimating production ceilings is that few pits are operating at capacity and that reliable quantative data is not available.

Basic assumptions for this study include continued existing construction practices, valid population projections, and production quantities to the levels recommended. Since the study concludes that there is an overall shortage of construction materials to meet the 17-year demand levels, conservation of gravel by incorporating innovative design methods is expected to affect the projections presented in this report. Therefore, a re-evaluation considering the amount of materials which can be saved will be necessary if new gravel-saving techniques are adopted.

Two options are presented for optimizing the production levels. Option No. 1 assumes that the Eklutna River floodplain, Site ER-9; Glacier Creek, Site TA-5; Site ER-10; and the Sand Lake area all contribute to the supply. Option No. 2 assumes that the above named sites do not contribute to the supply and also that sand and gravel extractions from the Sand Lake area are terminated as of December 31, 1982. It may be anticipated that should major construction projects be undertaken, existing pits could be expanded in terms of production equipment. However, increased production to satisfy a large demand project with sand and gravel materials would increase the deficits indicated in this report and would therefore result in faster depletion of the existing resources and possibly earlier termination dates than these projected.

Production levels, as listed in Tables III.12 through III.19, assume two distinct options:

Option 1 Assumes all sources, including Sand Lake; ER-9, Eklutna River; TA-5, Glacier Creek; and ER-10 contribute to the supply.

Option 2 Assumes the Sand Lake sites are closed for further production as of December 31, 1982; ER-9, Eklutna River and TA-5, Glacier Creek, are not developed (or they are not capable of recharging and therefore are not renewable); and ER-10 is returned to the Native Corp. and is non-producing.

Option 1 is a best case presentation, while Option 2 is the worst case.

Option 1 predicts a 434,000 cubic yard deficit in 1984, a 2,066,500 cubic yard deficit in 1985 and no deficit in 1986. However, the 1985 deficit would create a pent up demand for sand and gravel. This demand may carry forward to 1986 and affect the estimated sand and gravel requirements for that year.

Option 2 predicts a small deficit in 1983 which can be overcome by increased production in any of the producing sites. By 1984, the estimated deficit increases to 1,662,000 cubic yards and continues at deficit levels in excess of a million cubic yards per year beyond 1986.

It is our opinion that the marketplace will not permit continuing deficits of the magnitude projected to exist. Efforts will be made by private enterprise to satisfy such short-fall quantities by either developing new areas of supply or implementing construction methods which conserve sand and gravel. Methods to reduce sand and gravel consumption are discussed more fully in Section III.E.

TABLE III.12. INTEGRATED PRODUCTION LEVELS (in cubic yards)

OPTION NO. 1

Demand = 2,345,344 c.y. Year = 1983

Material Site	Production	Reserves Remaining
SL-1	50,000	50,000
SL-2	100,000	800,000
SL-3	100,000	600,000
SL-6	40,000	0
SL-7	50,000	0
SL-9	50,000	30,000
SL-10	40,000	0
SL-11	50,000	150,000
1233-1	53,000	0
2634-1	100,000	1,400,000
ER-1	0	900,000
ER-3	30,000	70,000
ER-4	50,000	150,000
ER-5	50,000	200,000
ER-6	100,000	500,000
ER-7	100,000	500,000
ER-8	30,000	0
ER-10	250,000	1,750,000
TA-2	0	23,000
TA-3	0	35,000
ER-9	*	1,200,000
TA-5	*	3,500,000
	1,243,000	12,108,000

* Under development for 1984

Supply (local)	1,243,000
Alaska RR Supply	1,250,000
Total Supply	2,493,000
DEFICIT	**0**

TABLE III.13. INTEGRATED PRODUCTION LEVELS (in cubic yards)
OPTION NO. 1

Demand = 4,242,345 c.y. Year = 1984

Material Site	Production	Reserves Remaining
Sl-1	50,000	0
SL-2	200,000	600,000
SL-3	200,000	400,000
SL-9	30,000	0
SL-11	150,000	0
2634-1	200,000	1,200,000
ER-1	100,000	800,000
ER-3	70,000	0
ER-4	150,000	0
ER-5	200,000	0
ER-6	200,000	300,000
ER-7	200,000	300,000
ER-10	250,000	1,500,000
TA-2	23,000	0
TA-3	35,000	0
ER-9*	200,000	1,000,000
TA-5**	300,000	3,200,000
	2,558,000	9,300,000

* Assumes development and production by 1984
** Production = 80 $\frac{\text{cars}}{\text{Day}}$ x 80 $\frac{\text{T. CY}}{\text{1.67 T. car}}$ x 100 days = 383,000 cy/yr

Supply (local)	2,558,000
Alaska RR Supply	1,250,000
Total Supply	3,808,000
DEFICIT	**434,000**

TABLE III.14. INTEGRATED PRODUCTION LEVELS (in cubic yards)
OPTION NO. 1

Demand = 5,566,500 c.y. Year = 1985

Material Site	Production	Reserves Remaining
SL-2	250,000	350,000
SL-3	250,000	150,000
2634-1	250,000	950,000
ER-1	200,000	600,000
ER-6	200,000	100,000
ER-7	200,000	100,000
ER-9	300,000	700,000
ER-10	250,000	1,250,000
TA-5	350,000	2,850,000
	2,250,000	7,050,000

Supply (local)	2,250,000
Alaska RR Supply	1,250,000
Total Supply	3,500,000
DEFICIT	**2,066,500**

TABLE III.15. INTEGRATED PRODUCTION LEVELS (in cubic yards)
OPTION NO. 1

Demand = 2,800,643 c.y. Year = 1986

Material Site	Production	Reserves Remaining
SL-2	250,000	150,000
SL-3	150,000	0
2634-1	250,000	700,000
ER-1	200,000	400,000
ER-6	100,000	0
ER-7	100,000	0
ER-9	300,000	400,000
ER-10	250,000	1,000,000
TA-5	350,000	2,500,000
	1,950,000	5,150,000

Supply (local)	1,950,000
Alaska RR Supply	1,250,000
Total Supply	3,200,000
DEFICIT	**0**

TABLE III.16. INTEGRATED PRODUCTION LEVELS (in cubic yards)
OPTION NO. 2

Demand = 2,345,344 c.y. Year = 1983

Material Site	Production	Reserves Remaining
1233-1	53,000	0
2634-1	250,000	1,250,000
ER-3	70,000	30,000
ER-4	50,000	150,000
ER-5	50,000	200,000
ER-6	100,000	500,000
ER-7	100,000	500,000
ER-8	30,000	0
ER-10	250,000	250,000
TA-2	23,000	0
TA-3	35,000	0
	1,011,000	2,880,000

Supply (local)	1,011,000
Alaska RR Supply	1,250,000
Total Supply	2,262,000
DEFICIT	**84,000**

TABLE III.17. INTEGRATED PRODUCTION LEVELS (in cubic yards)
OPTION NO. 2

Demand = 4,242,345 c.y. Year = 1984

Material Site	Production	Reserves Remaining
2634-1	300,000	950,000
ER-3	30,000	0
ER-4	150,000	0
ER-5	200,000	0
ER-6	200,000	300,000
ER-7	200,000	300,000
ER-10	250,000	0
	1,330,000	1,550,000

Supply (local)	1,330,000
Alaska RR Supply	1,250,000
Total Supply	2,580,000
DEFICIT	**1,662,000**

TABLE III.18. INTEGRATED PRODUCTION LEVELS (in cubic yards)
OPTION NO. 2

Demand = 5,566,500 c.y. Year = 1985

Material Site	Production	Reserves Remaining
2634-1	400,000	550,000
ER-6	300,000	0
ER-7	300,000	0
	1,000,000	550,000

Supply (local)	1,000,000
Alaska RR Supply	1,250,000
Total Supply	2,250,000
DEFICIT	**3,316,500**

TABLE III.19. INTEGRATED PRODUCTION LEVELS (in cubic yards)
OPTION NO. 2

Demand = 2,800,643 c.y. Year = 1986

Material Site	Production	Reserves Remaining
2634-1	400,000	150,000
	400,000	150,000

Supply (local)	400,000
Alaska RR Supply	1,250,000
Total Supply	1,650,000
DEFICIT	**1,200,000**

D. PROJECTED GRAVEL EXTRACTION SITE TERMINATIONS

Section III.C, INTEGRATED PRODUCTION LEVELS, presented two options for establishing production volumes. Coincident with production is depletion. Depletion of each mining site is a direct result of extraction to satisfy demand.

Option 1 is presented on Tables III.12 through III.15, and Option 2 is presented on Tables III.16 through III.19. Based on the data projected in these Tables, Table III.20 lists by Option and by site designation the probable year for termination. The estimated termination year for each site are not fixed to any degree. They represent the best engineering estimate available at the time of the study and are based solely upon estimated depletion of the sand and gravel resource at each site.

Restoration and/or redevelopment should be initiated concurrently with the extraction operation but not later than the year following the listed termination. For example, if the termination year is 1985, then restoration, in accordance with an approved restoration plan, should be initiated not later than the spring of 1986.

E. SAND AND GRAVEL RESOURCE MANAGEMENT ALTERNATIVES

Introduction

The results from previous sections of this report lead to the conclusion that sometime in the time period between 1983 and 1986, demand will exceed supply based upon existing conditions and construction requirements.

The purpose of this section is to suggest resource management alternatives. First is an overview of alternatives to existing construction practices, those required by the Municipality and those practices by the construction industry. These are concepts which might be employed to reduce the sand and gravel demand. Secondly, are suggestions of other areas which should be investigated, either by the Municipality or by private enterprise which might lead to new supplies of sand and gravel.

TABLE III.20. PROJECTED GRAVEL EXTRACTION SITE TERMINATIONS

Site No.	Current Status	Future Quantities (c.y.) (17-year Total) Option 1	Option 2	Termination Year Option 1	Option 2
1233-1	D	53,000	53,000	1983	1983
1521-1	D	0	0	1982	1982
2028-1	D	0	0	--	--
2130-1	D	0	0	--	--
2135-1	D	0	0	1982	1982
2235-1	D	0	0	1982	1982
2521-1	D	0	0	1982	1982
2533-1	D	0	0	1982	1982
2533-2	D	0	0	1982	1982
2534-1	D	0	0	1982	1982
2631-1	D	0	0	--	--
2634-1	A	1,500,000	1,500,000	1990	1987
TA-1	D	0	0	1982	1982
TA-2	D	23,000	23,000	1984	1983
TA-3	A	35,000	35,000	1984	1983
TA-4	D	0	0	1982	1982
TA-5	A	6,500,000	272,000	2000	--
TA-6	D	0	0	1982	1982
TA-7	D	0	0	1982	1982
TA-9	D	0	0	1982	1982
TA-10	D	0	0	1982	1982
TA-11	D	0	0	1982	1982
TA-12	D	0	0	1982	1982
ER-1	A	900,000	0	1988	--
ER-2	D	0	0	1982	1982
ER-3	D	100,000	0	1984	1984
ER-4	A	200,000	200,000	1984	1984
ER-5	A	250,000	250,000	1984	1984
ER-6	A	600,000	600,000	1986	1985
ER-7	A	600,000	600,000	1986	1986
ER-8	P	30,000	30,000	1983	1983
ER-9	A	1,200,000	0	1988	1982
ER-10	A	500,000	500,000	1984	1984
SL-1	D	100,000	0	1984	1982
SL-2	A	900,000	0	1987	1982
SL-3	A	700,000	0	1986	1982
SL-4	D	0	0	1982	1982
SL-5	D	0	0	1982	1982
SL-6	A	40,000	0	1983	1982
SL-7	A	50,000	0	1983	1982
SL-8	A	0	0	1982	1982
SL-9	A	80,000	0	1984	1982
SL-10	A	40,000	0	1983	1982
SL-11	P	200,000*	0	1984	--

* First Year - 1983

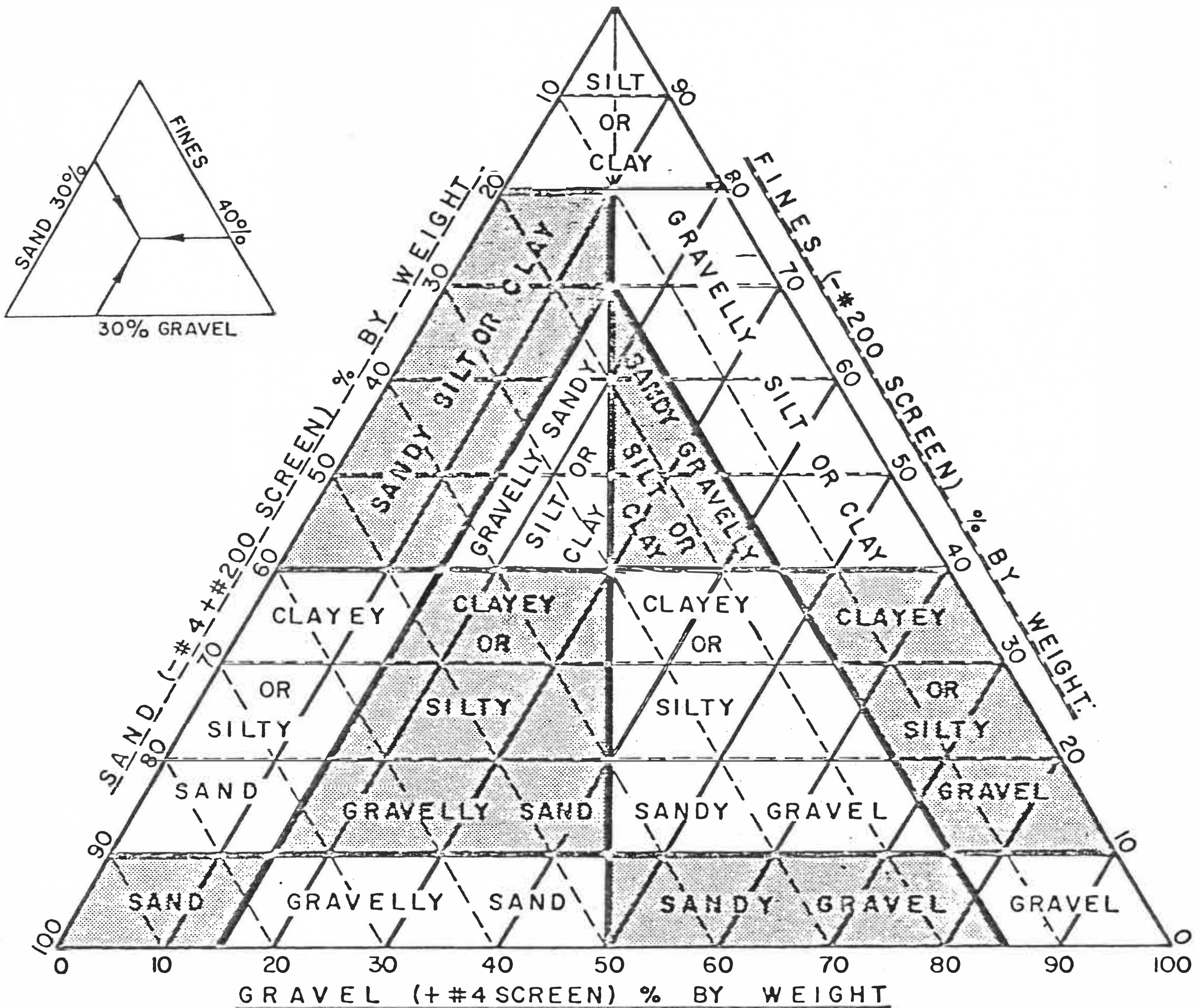
On-shore deposits of sand and gravel constitute a finite source. Supplies of good quality material are not unlimited. In some ways, the future problems with sand and gravel supplies can be compared to the world-wide oil shortage problems recently experienced. Shortages will cause increased prices of any commodity. The same economic principle which governs the Organization of Petroleum Exporting Countries (OPEC) will govern the local gravel industry. As supplies diminish (i.e., sites are closed), those companies or individuals with operating reserves of sand and gravel will benefit economically from increasing demand.

Construction Practices on Marginal Soils

This section is intended as a simplified explanation and discussion of engineering principles and construction practices in use at the present time in relation to poor or marginal soils conditions. It is included for the benefit of readers not familiar with engineering and construction practices on poor soils and should be of assistance in the synthesis of the subsection entitled, Methods to Reduce Demand.

Poorly drained lands underlain by clay-silts and silty sands, silty gravels, or peat deposits, are considered marginal for development purposes. Fine-grained silty soils attract capillary water. This is moisture drawn vertically in the space between soil particles sometimes from very deep sources. In freezing temperatures, this moisture continues to be drawn to the freezing zone and ice lenses are formed. These ice lenses continue to grow, causing "frost heaving", until thawing occurs. Subsequently, upon thawing, excessive moisture from the ice lenses softens the soils causing the loss of bearing strength, which, in the case of streets, results in pavement break-up and potholes, or noticeable differential settlement. Fine grained soils, or soils containing large amounts of fine particles, are therefore considered frost-susceptible and classified in accordance with the degree of frost-susceptibility into four groups, F-1 through F-4, as determined by the percentage of very fine particles 0.02mm or smaller (see Figure III.1, Soils Classification Chart), where F-1 has the lowest frost susceptibility and F-4 has the highest frost susceptibility.

In order to completely prevent frost heaving, or frost action, which occurs during the formation of ice lenses near the surface, the frost-susceptible soils must be replaced with non-frost-susceptible (NFS) material to a depth equal to the maximum ground frost



NONFROST SUSCEPTIBLE SOILS ARE INORGANIC SOILS CONTAINING LESS THAN 3% FINER THAN 0.02 mm.
GROUPS OF FROST-SUSCEPTIBLE SOILS:

- F1 GRAVELLY SOILS CONTAINING BETWEEN 3 AND 20% FINER THAN 0.02 mm.
- F2 SANDY SOILS CONTAINING BETWEEN 3 AND 15% FINER THAN 0.02 mm.
- F3 a. GRAVELLY SOILS CONTAINING MORE THAN 20% FINER THAN 0.02 mm. AND SANDY SOILS (EXCEPT FINE SILTY, SANDS) CONTAINING MORE THAN 15% FINER THAN 0.02 mm.
  - b. CLAYS WITH PLASTICITY INDEXES OF MORE THAN 12. EXCEPT VARVED CLAYS.
- F4 a. ALL SILTS INCLUDING SANDY SILTS.
  - b. FINE SILTY SANDS CONTAINING MORE THAN 15% FINER THAN 0.02 mm.
  - c. LEAN CLAYS WITH PLASTICITY INDEXES OF LESS THAN 12.
  - d. VARVED CLAYS.

SOILS CLASSIFICATION CHART

FIGURE III.1

penetration depth. This is expensive and impractical for most construction purposes. Therefore, the most common practice has been to place 1-1/2 to 3-1/2 feet of NFS materials on top of the frost-susceptible soils in accordance with the degree of frost-susceptibility of the sub-soils. The non-frost-susceptible, or NFS, materials consist of natural in-place sand and gravel deposits, or processed materials which contain less than 3 percent, by weight, of particles finer than 0.02mm in diameter. This is a definition used by the Army Corps of Engineers and is widely accepted in the construction industry. (see Figure III.2, Typical Residential Street Section)

This practice offers "adequate" protection against frost action for streets and utilities. However, enormous amounts of NFS sand and gravel materials are used, particularly where subsoils are classified as F-4. Approximately 600 cubic yards (1,100 tons) of NFS sand or gravel is used in the construction of 100 lineal feet of a 36-foot wide urban street with sidewalks on both sides. This excludes the gravel used in the construction of utilities. Gravel for utilities varies considerably with utility type (storm, sanitary sewer or water mains), size, depth, and foundation requirements for these utilities.

The previous discussion does not apply to highly organic soils such as peat. In this case, the peat must be completely removed and the excavation, whether for utilities, streets of building foundations, must be filled and compacted with Type I, II or III material. Five to eight foot excavations are ordinary and 12 to 15 foot excavations are not uncommon in some areas of the Municipality.

Sand and gravel materials are further classified for construction purposes in accordance with their particle size distribution as a fractional percentage by weight. The distribution of particle sizes for a given type of sand and gravel material is usually presented graphically on a "gradation chart." The gradation chart is a graphic plot of particle sizes, commonly in millimeters, versus percentage finer by weight of the particle's fractions. This is determined by shake-screening a laboratory sample of the material after oven drying, and weighing the amounts retained on a series of standard sieves with known screen mesh sizes. Subsequently, the percentages finer by weight of each particle fraction is computed and the results are plotted on a gradation chart. A typical example of a gradation chart indicating the limits for Type I and Type II material is illustrated on Figure III.3.

FIGURE III.2

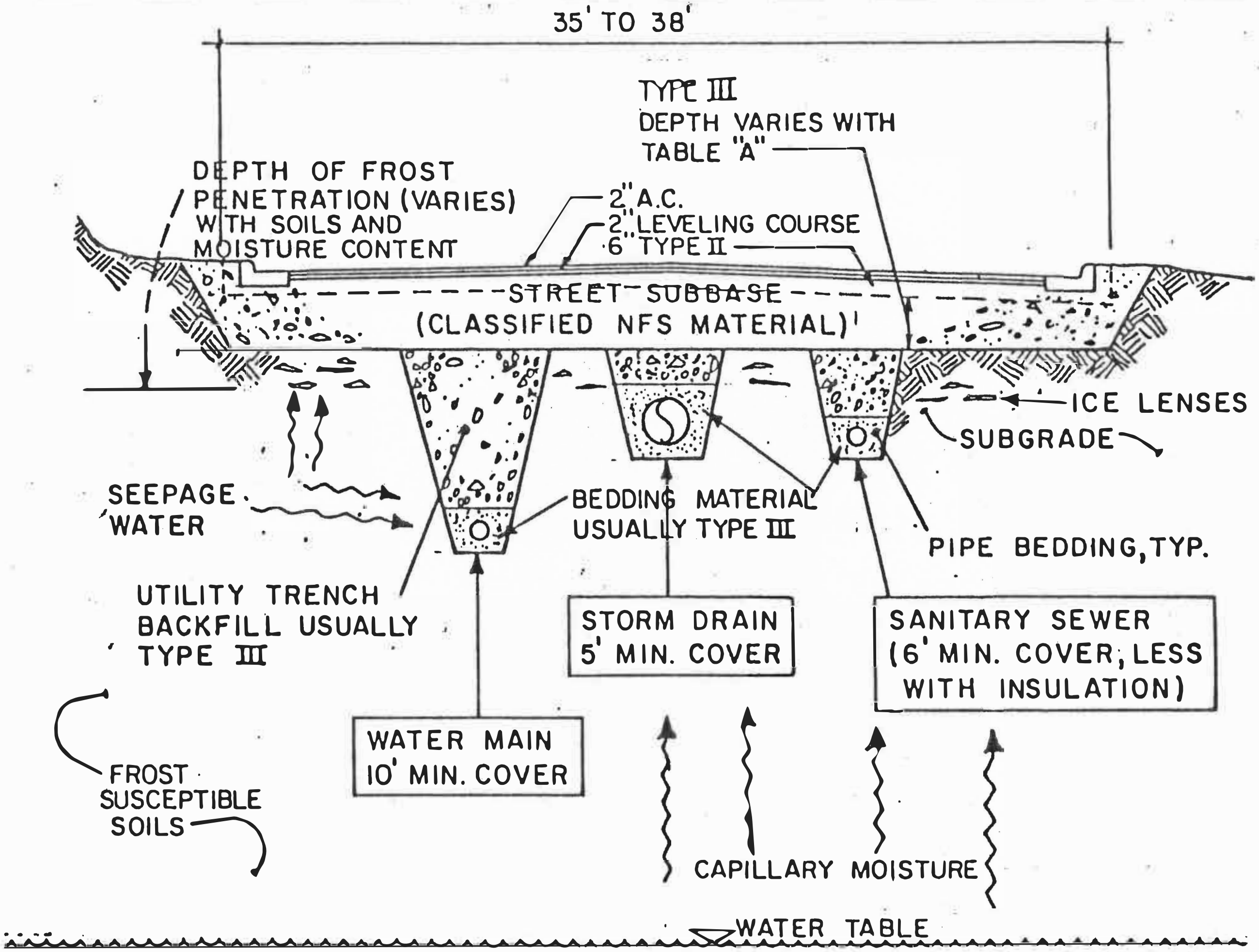


TABLE A

MUNIC. OF ANCHORAGE, DEPT. OF PUBLIC WORKS, BASED ON CORPS OF ENGINEERS REDUCED SUBGRADE STRENGTH METHOD AS MODIFIED BY DEPT. OF PUBLIC WORKS

SUBGRADE SOILS FROST CLASSIFICATION	DEPTH NFS (RESIDENTIAL STREETS) SUBBASE (FEET)
F-1	1.5
F-2	1.7
F-3	2.7
F-4	3.7

TYPICAL RESIDENTIAL STREET SECTION

FOR URBAN AREAS (DEFINITION SKETCH)

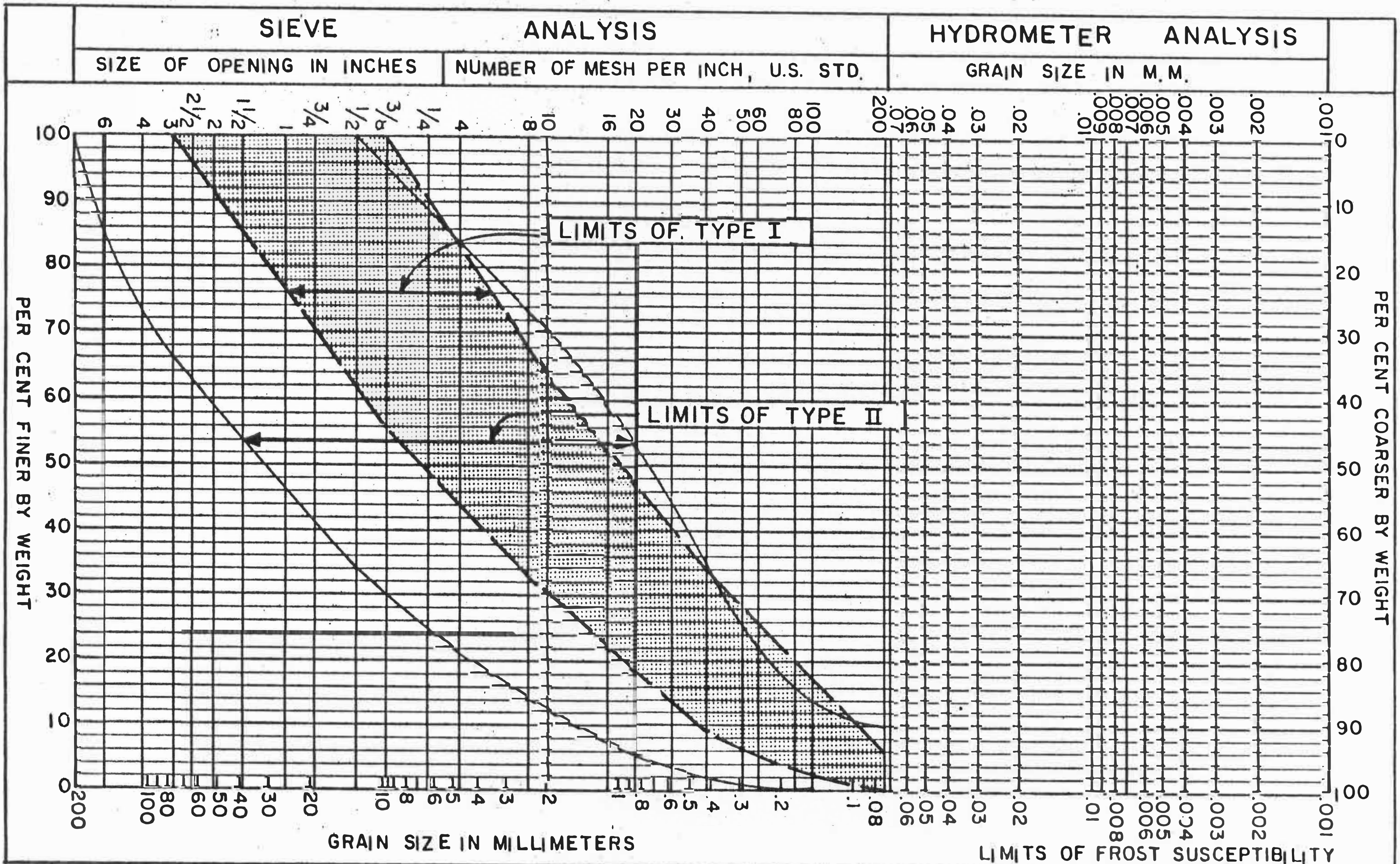

SIEVE ANALYSIS
SIZE OF OPENING IN INCHES
NUMBER OF MESH PER INCH, U.S. STD.
HYDROMETER ANALYSIS
GRAIN SIZE IN M.M.
LIMITS OF TYPE I
LIMITS OF TYPE II
PER CENT FINER BY WEIGHT
PER CENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
LIMITS OF FROST SUSCEPTIBILITY

FIGURE III.3

For earthwork purposes, the Municipality of Anchorage Construction Specifications classified four types of material in accordance with gradation. It should be noted that in addition to gradation, the materials must meet certain other quality standards for specific purposes such as concrete, asphalt, etc. Most general-use classes of materials occur naturally and are excavated as "pit-run" material, while special purpose materials are often very difficult to find in natural deposits and must be obtained by mechanical processing. The processing usually consists of mechanical screening, crushing, washing, or remixing of the materials for specific purposes.

Type I through Type IV materials and Topsoil as specified in the Municipality's Standard Construction Specifications are explained as follows:

Type I - This material is used where non-frost susceptibility and strength are important. It is very well graded (containing a proportional mix of all particle sizes within the allowable grading limits) material with maximum particle size of 3 inches and up to 6 percent passing #200 sieve (approximately .07mm). See Figure III.3 for grading limits.

Type II - The maximum allowable particle size for this material is 8 inches with up to 10 percent passing the #200 sieve, the upper particle size limit for silt. This material is gravel, and can be F-1, frost susceptible; it is used as base course where strength is important. See Figure III.3 for grading limits.

Type III - This material is non-frost susceptible sand or gravel without any other grading limitations and is generally used as street sub-base. Sand Lake material sites have been the source for this type of material, generally furnished as pit-run sand.

Type IV - This classified material can be sand, gravel, or other materials free from organic material, frozen lumps, trash, lumber or other debris. This material may be frost-susceptible and is used as landfill and similar uses.

Topsoil - Class A-2, not less than 75 percent by weight passing the #100 sieve (0.15mm); Class A-4, not more than 80 percent by weight passing the #200 sieve (0.07mm).

There are several other gradation specifications for special purpose materials such as Leveling Course, Filter Material, Concrete Coarse Aggregate (see Figure III.4), Concrete Fine Aggregate (see Figure III.4), and Asphalt Mix Aggregates. For detailed specifications of these materials, we suggest the reader consult the Municipality of Anchorage Standard Specifications, June 1980.

Methods to Reduce Sand and Gravel Consumption

Based upon the 1975 report by the Greater Anchorage Area Borough Planning Department, entitled Future Land Use Alternatives of Sand Lake Gravel Pits, it has been known for some time that the supplies of sand and gravel are diminishing in the Municipality of Anchorage. In order to reduce consumption, there needs to be a justifiable basis for the proposed alternative construction method. Reductions in the use of sand and gravel should result from either small-scale laboratory testing with published results or closely monitored field testing of specific areas. The results of field testing, would become evident very soon if tests were instituted in the near future. Cooperation between the Department of Public Works, engineers and developer/construction firms would be a prerequisite to modifying existing standards for private projects. The Municipality could also adopt a field testing program on selected public projects.

The previous section discusses two major problems. One is capillary moisture being drawn upwards from the water table and the other is the amount of fine material (the percent passing a #200 sieve) in the subgrade and subbase. To eliminate either the moisture or the fine material would go a long way towards reducing the consumption of sand and gravel. The following discussion of geotechnical filter fabrics (GFF) suggests that there may be methods available today to reduce the problems of moisture and fines since, as a practical matter, neither can be eliminated.

The first use of geotechnical filter fabrics to reinforce roads was begun in 1926 by the South Carolina Highway Department. Tests up to 1935 reached the general conclusion that the installation of GFF reduced cracking, raveling and failures.

Design of pavement sections for today's highway traffic has changed considerably from the early days of road design. At present, the use of California Bearing Ratio (CBR) is the most commonly used test to determine the adequacy of stone base courses and soil

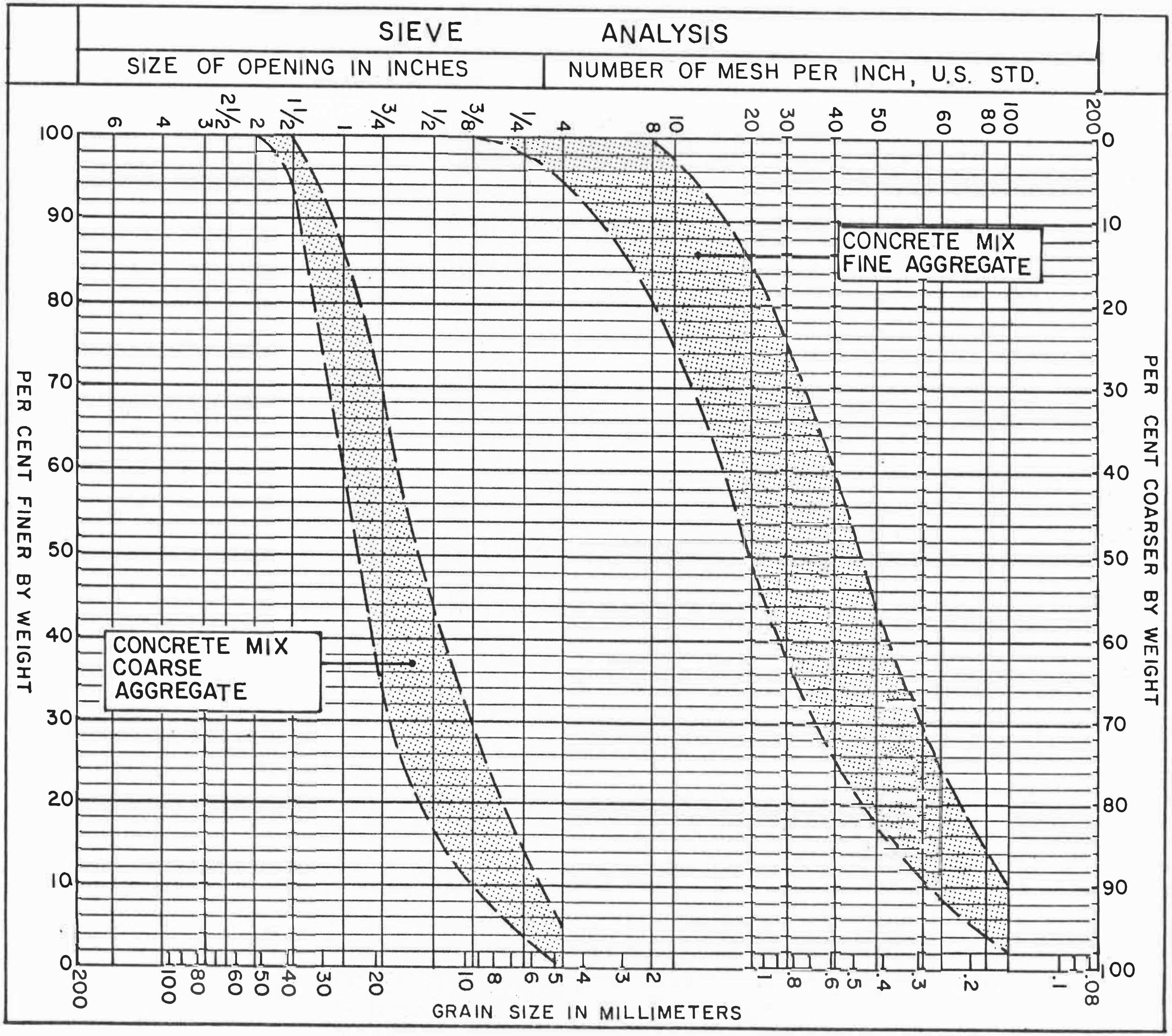

SIEVE ANALYSIS
SIZE OF OPENING IN INCHES
NUMBER OF MESH PER INCH, U.S. STD.
PER CENT FINER BY WEIGHT
PER CENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
CONCRETE MIX FINE AGGREGATE
CONCRETE MIX COARSE AGGREGATE

FIGURE III.4

subgrades. The higher the CBR, the stronger the material; the lower the CBR, the weaker the material. Based upon preliminary laboratory tests by DuPont, it has been found that GFF placed on soil will, acting alone, add as much a 4 CBR percent to the soil.

The Asphalt Institute's method of designing a flexible pavement system is based upon the CBR of the soil subgrade as well as the volume of traffic using the road. In applying this method to pavement design, it has been found that the installation of GFF between the in-situ soil and the sub-base rock results in a reduction of the required sub-base rock of between 60% to 70%.

Geotechnical filter fabrics perform two major functions in roadway design. First, they act as a separator between the sub-grade and the sub-base, thereby preventing the loss of the sub-base material into the weaker soil sub-grade. Secondly, and perhaps most importantly, the fabric prevents the migration of frost-susceptible fines vertically from reaching the sub-base material.

From the book "Construction and Geotechnical Engineering Using Synthetic Fabrics", by Robert M. Koerner and Joseph P. Welsh, we submit two examples.

EXAMPLE 1

CASE 2. ROAD CONSTRUCTION ON MUSKEG. A test section of road in the Tongass National Forest near Petersburg, Alaska, consisted of about 10 feet of muskeg at its surface and was to be used to support logging traffic. The average vane shear strength of the peat was 250 pounds per square foot and the saturated soil had a water content of approximately 960 percent. The test section was subdivided in stations along its length into zones of a double layer of fabric, a single layer of fabric, and no fabric. The fabric used was Fibretex. The test was planned to illustrate the differences in thickness of rock fill required to reach a stable and permanent road surface. The rock fill was highly variable with size ranging from 4 feet to sand size.

Settlement and thickness measurements indicated that where no fabric had been used, depths of fill from 5 to 7.5 feet were required. With fabric (either single or double thickness) the required depth of fill was 3.5 and 5.5 feet. Thus the savings in rock fill amounted to about 28 percent. Clearly, the presence of fabric prevented local bearing capacity failures from occurring and proved the value of fabric utilization. (pg. 95)

EXAMPLE 2

CASE 5. In a related problem of pavement deterioration, the Maine Department of Transportation has used fabrics to prevent the upward pumping of silt through pavement during spring thaw, ("frost boils"). In a series of experimental efforts on Route 150 in Parkman, Maine, it was found that the placement of fabric, in this case Bidim, on top of the soil subbase and beneath the clean gravel was successful in preventing the silt from surfacing. Other attempts were made at placing the fabric directly on the deteriorated pavement, then the gravel and a new asphalt surface on top. This approach was apparently also successful. Test holes were excavated and no silt was noticeable on top of the fabric or in the gravel, but upon removal of the fabric the underlying soil was seen to be covered with a thin layer of saturated fines. these fines had apparently been stopped from upward migration by the fabric, which acted as a separating filter material. (p. 115)

Geotechnical filter fabrics have been recognized by The American Society of Testing and Materials (ASTM) as an adaptation of textiles and has established Committee D13.61 to evaluate, modify and/or suggest test methods for geotechnical fabrics.

Problems involving subgrade reinforcement appear to be particularly well suited for GFF utilization. The concept is theoretically sound since the fabric decreases the stress level in the subgrade soil by spreading the imposed loads over large areas and thereby decreasing the intensity. A decrease in stress means less likelihood of a failure and/or less settlement.

In February 1977, the U.S. Army corps of Engineers issued TECHNICAL REPORT S-77-1, entitled Investigation of Construction Techniques for Tactical Bridge Approach Roads Across Soft Ground. (A complete copy of this report has been forwarded to the Municipality Planning Department under separate cover.) This report tested two fabrics under controlled field conditions. One fabric, called "Bidim", is pervious and another labeled T-16, and is impervious to water. T-16 is a neoprene-coated one-ply woven nylon membrane. Tests were made on a subgrade with a CBR of 0.7 to 1.0 (a heavy, soft clay). A 2-inch wearing surface of crushed stone was used in both cases in order to measure the rut depths at various traffic intervals. Traffic loads were imposed by a loaded 5-ton, tandem axle military dump truck.

The conclusion of the test results were that the performance of T-16 was outstanding. After 5,500 loadings, the average rut depth was only 1.8 inches. In comparison, the

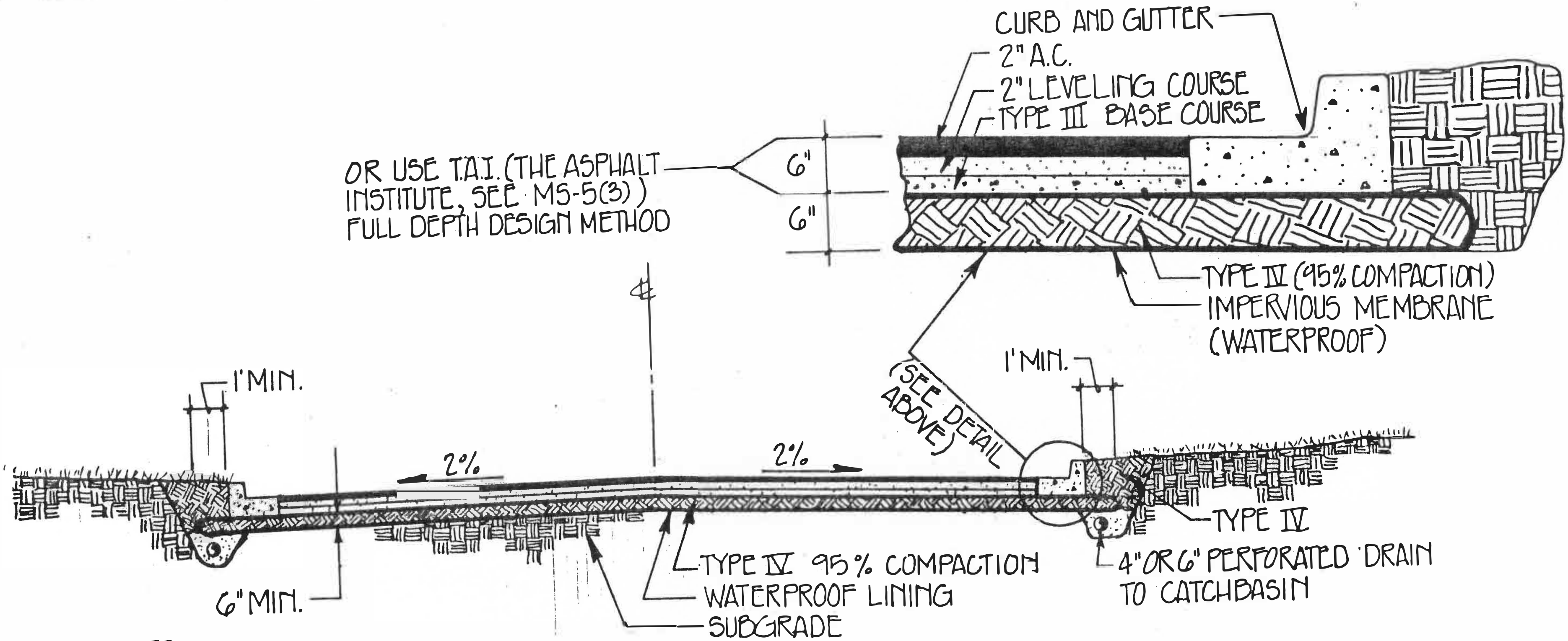
"Bidim" developed 2.6-inch ruts after only 200 loadings. We recommend, based on the results of this test report, that T-16 be tested under Anchorage weather conditions.

Figure III.5 represents a Membrane Encapsulated Soil Layer solution for gravel reduction. This is an adaptation of using a single layer of T-16 directly on the subgrade. Also note that the subgrade is sloped at the same percentage slope as the finished street surface and perforated drains have been installed on both sides to reduce the volume of capillary water which reaches the bottom of the membrane. A test section such as is shown in Figure III.6 would require the relocation of utilities (storm sewer, sanitary sewer and water mains) to outside of the curb lines. Compared to Figure III.3, this would be a reduction of 3.2 feet (3.7' - 0.5') of NFS sand and gravel.

In January 1982, the Transportation Engineering Journal of the American Society of Engineers published an article entitled, Full Depth and Granular Base Course Design for Frost Areas. The conclusion of this 7-year test was that, " . . . 2. The Corps of Engineers reduced subgrade strength highway pavement frost design was found to be the upper bound or conservative design for these test conditions. . . . Further controlled traffic and field testing is recommended to revise the Corps of Engineers reduced subgrade strength design for highway pavements in seasonal frost areas."

A complete copy of the text of this 1982 article has been forwarded to the Municipal Planning Department under separate cover.

Utilities installations also require enormous volumes of sand and gravel when installed under current specifications. Water mains are installed with 10 feet of cover in all cases and sanitary sewer with 6 feet of cover. As shown on Figure III.2, these utilities plus the storm sewer are not located within the paved street section. Being located in the streets, these utilities must be installed at these depths since the frost penetration is deeper on paved streets that are plowed in the winter time. Also, by being constructed in the streets, the entire trench volumes must be backfilled and compacted with at least Type III NFS material. Alternatives to this standard installation are shown in Figure III.6. The use of insulation, installed in the field, on water mains and sanitary sewer mains would allow these utilities to be raised. Installing them outside of the paved, plowed streets would allow the snow cover to add to the insulation protecting pipes from freezing. Benefits of

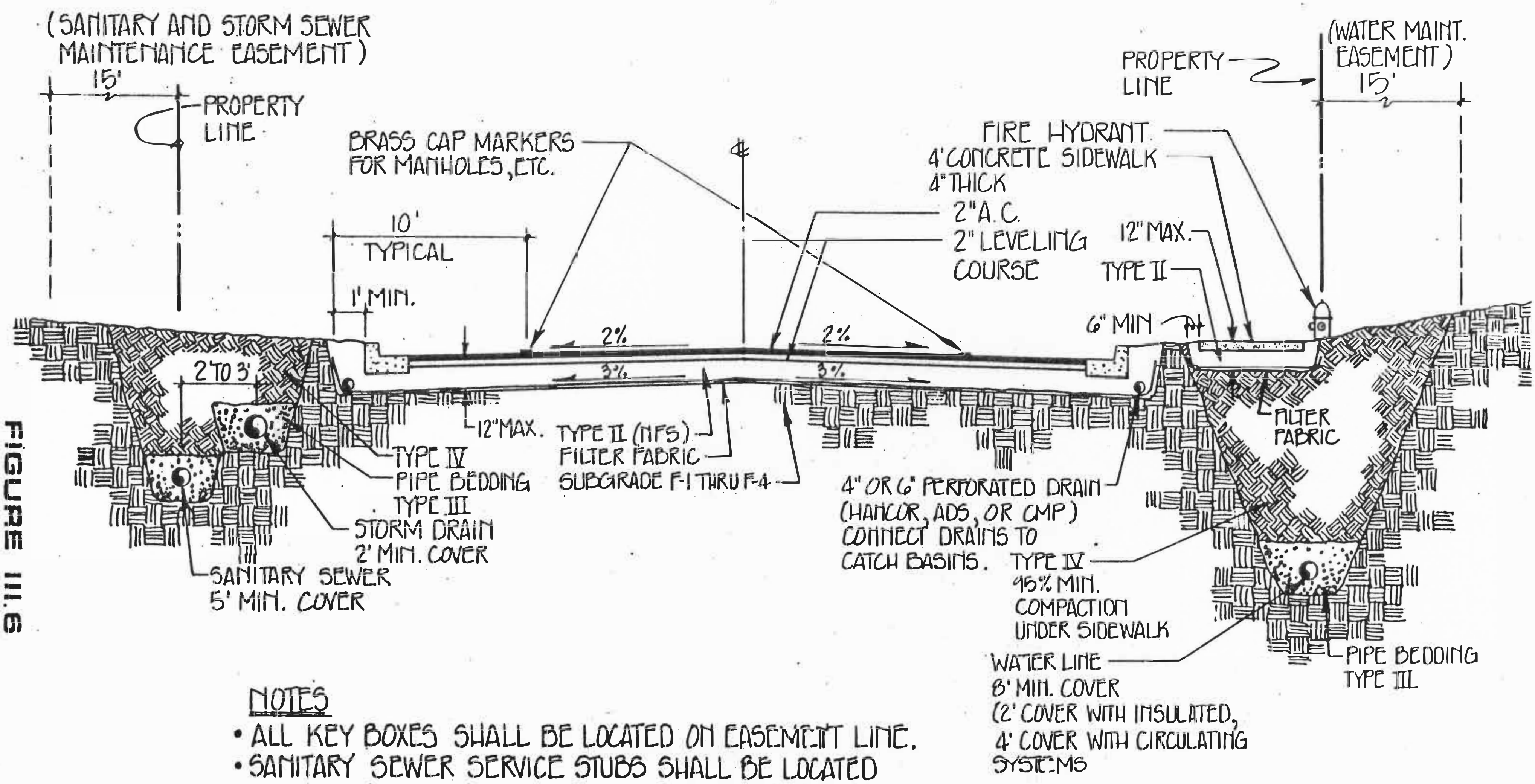


NOTE:
TYPE IV MATERIAL, WHEN TOO SILTY, CAN BE USED ONLY DURING DRY WEATHER DUE TO COMPACTION DIFFICULTIES

FIGURE III.5

MEMBRANE ENCAPSULATED SOIL LAYER

FIGURE III.6



NOTES

- ALL KEY BOXES SHALL BE LOCATED ON EASEMENT LINE.
- SANITARY SEWER SERVICE STUBS SHALL BE LOCATED ON EASEMENT LINE.
- LOCATION OF MANHOLES, SERVICE CONNECTS, AND KEY BOXES SHALL BE MARKED ON PAVEMENT 10' FROM BACK-OF-CURB USING BRASS CAP MARKERS.
- WHEN 95% COMPACTION IS REQUIRED, TYPE IV MATERIAL CAN BE USED ONLY DURING DRY WEATHER.

ALTERNATIVE STREET AND UTILITY CROSS-SECTION

not disturbing the street subgrade, pavement, etc., when repairs are required also adds to the desirability of relocating these utilities outside of the paved area. In addition, the trenches for utilities outside of the paved street seciton could be backfilled with other than NFS material.

Revisions can be made to existing specifications for reduction of sand and gravel consumption. The information contained herein and the associated figures in the text offer some suggestions which should be considered in new areas of construction.

Off-Shore Mining

Attached to this report in Appendix F, is an article by D.S. Cottell entitled, Offshore Recovery of Sand and Gravel: An Alternative to Inland Mining. This article is particularly interesting because of the following:

1. Many countries have explored their continental shelves and found considerable deposits of recoverable aggregates.

2. Millions of tons of aggregates are now being mined in off-shore locations each year.

3. Other areas of the world have experienced aggregate shortages.

4. Specific studies of local off-shore aggregate deposits have been done by a majority of the east and west coast seaboard states and all of these studies have discovered vast amounts of exploitable mineral aggregates.

The area of Cook Inlet to the north and northwest of Point Woronzof appears, from present indications, to offer an excellent potential supply of minable aggregates. However, certain major difficulties are associated with off-shore mining including but not limited to:

1. Very high initial capital investment
2. The need for on-shore facilities
3. Lack of sufficient, credible subsurface information

4. The high cost of off-shore exploration
5. Problems associated with mineral rights and permits which allow subsurface extraction

Information on the subsurface quality of aggregates is virtually non-existent in Cook Inlet. Some dredging has been done for specific purposes. The Corps of Engineers has dredged approximately one million cubic yards of material for the purpose of clearing navigational channels. Chugach Electric has dredged considerable areas for their underwater cable routes crossing Knik Arm, but samples have not been taken for the specific purpose of determining whether or not a viable, extractable resource exists in the area.

Persistent rumors exist with regard to the potential of recoverable precious minerals combined with the aggregates. Discounting completely any other recoverable minerals, it is recommended that a special study be authorized to investigate the potential of Cook Inlet as a future source of sand and gravel supplies within the Municipality of Anchorage.

A second article of particular interest is included in Appendix G. This article is entitled, "Record Sand and Gravel Volume Delivered to River Thames", and is included in this report to further emphasize that other areas of the world are presently exploiting off-shore aggregate sources due to the lack of on-shore minable reserves.

Recommendations

This section presents recommendations and concepts for future projects which could save large quantities of sand and gravel. The need for conservation of all our resources, especially in view of the new technologies, cannot be ignored. Innovation and experimentation offer the opportunity to save what is available today for tomorrow's use.

The Municipality has, in our opinion, at least three options:

1. Continue with current construction policies and enforce current specifications as they related to the requirements for sand and gravel

2. Revise current policies and specifications by adoption of less stringent requirements for aggregate classifications

3. Continue with current policies and specifications but institute or authorize a systematic, monitored experimental program which will allow the use of feasible alternatives.

We suggest implementation of the following measures by a combined committee chaired by an appointee of the Mayor with concurrence by the Assembly, including a representative of the Public Works Department, members of the private professional engineering sector, and a representative of the construction industry in order to establish future test criteria and locations. This group would monitor results and make recommendations for revisions to existing street and utility criteria. Our recommendations include:

1. Where prudent, reduce street width requirements

2. Where feasible, construct sidewalks only on one side of the street

3. Use GFF, both pervious and impervious, for sections of roadways in the new construction, on an experimental basis, at selected locations using projected high traffic volume areas as the prime test areas (see Figures III.6 and III.7).

4. Revise the locations of utilities per Figure III.7 on a test basis as follows:

    a. Combine the storm sewer and sanitary sewer in a common trench outside of the paved roadway section.

    b. Experiment with a minimum cover of 4'-0" on storm sewer and sanitary sewer with all pipe, manholes and under lids field sprayed with a minimum of 2" of a rigid closed cell, two component urethane foam and spray coated with a waterproof elastomeric coating.

    c. Experiment with installation of water mains with six feet of cover outside of the paved roadway section provided they are insulated to the same specification as item b. above. This should initially be used on water mains which are looped or which do not result in deadends.

d. Experiment with perforated 4" or 6" diameter, rigid polyvinyl chloride (PVC) pipe laid to grade as subdrains on both sides of the roadway to remove free moisture accumulations between the interface of the subgrade and NFS subbase material (see Figures III.5 and III.6).

5. If revision of utilities locations to positions outside of the paved roadway sections is servicable, require utility easements on private property adjacent to the right-of-way lines. Suggested easement widths are 10 feet minimum. (This may be most easily accomplished in the review process for new plats.)

6. It is also recommended that the Federal Government, the State of Alaska, or the Municipality of Anchorage prepare a study of Cook Inlet for the purpose of determining aggregate reserve quality and quantity.

F. RECHARGE ANALYSIS

Braided streams and rivers, such as Glacier Creek and the Eklutna River, are generally good sources for construction materials. Their banks are typically prone to erosion and, during high flows, eroded bank material is transported downstream by rolling and sliding along the river bed. As the flood recedes, the river's capacity to transport this bed load decreases, and aggradation (raising of the stream bed elevation) results. The active channel eventually seeks a new, "lower" route and as aggrading continues, the active channel shifts back and forth across the floodplain, leaving extractable sand and gravel outside of the active channel.

In scraping a braided floodplain for gravel, it is important that the regime of the river not be drastically changed. Generally, the bed of an active channel should not be disturbed. This ensures continued conveyance of both water and bed load. Additionally, it reduces the potential hazard to fish by maintaining natural conditions, such as water depth, velocity, temperature, and dissolved oxygen concentration. Excavation of the floodplain should not extend below the water surface elevation of the active channel, and proper drainage of the site should be provided so that ponding and the development of side channels does not occur. For comprehensive guidelines in site planning, operation, and closure, refer to Gravel Removal Guidelines Manual for Arctic and Subarctic Floodplains, prepared for the U.S. Fish and Wildlife Service.

Several empirical methods have been developed to estimate a river's ability to transport bed load. They include the Einstien Equation, the Meyer-Peter and Muller Equation, the Colby Method, and the Slurry Fluid Method. These methods provide an estimate of the amount of material passing through a cross-section per unit time, given the river's discharge. This information may be extrapolated to yield the river's recharge capacity (or rate of accumulation of bed load on the floodplain) by applying the characteristics of the river's discharge hydrograph (a plot of discharge vs. time). Discharge records are therefore a crucial part of any recharge analysis. In a case where no published data exists, statistical or deterministic approaches may be used for predicting a typical discharge hydrograph. Twelve years of record are available for average daily discharges at Glacier Creek. No data, however, is available for the Eklutna River.

The Meyer-Peter and Muller Equation was chosen for this study because it is suitable for coarse-material channels; whereas, the others are more applicable to sandbed channels. Converted to units used in the United States, it is:

$$q_B = 1.606 \left[3.306 \left[\frac{Q_b}{Q} \right] \left[\frac{D_{90}^{1/6}}{n_b} \right]^{3/2} Y_o S - 0.627 D_m \right]^{3/2}$$

where:

q_B = recharge bed load rate in tons per day per foot of width

$\frac{Q_b}{Q}$ = multiplier determined by channel geometry and bed and bank roughness

D_{90} = grain size diameter for which 90% of the bed material (by weight) is smaller; determined by gradation analysis in millimeters

n_b = depth stream bed roughness (Manning's "n")

y_o = depth of flow, in feet

S = energy slope, in feet/feet

D_m = effective diameter of the bed material, equal to $\sum \frac{P_i D_i}{100}$, where Pi is the percentage of bed material (by weight) of grain size Di; determined by gradation analysis; in millimeters

Other variables required in the calculations are:

n_w = stream bank roughness

w = topwidth of flow area; in feet

Recharge analysis may be performed as follows:

1. Field Investigation

   a. Survey a representative cross-section in the reach under consideration, or several if there are constrictions, expansions, or other significant irregularities in the floodplain.

   b. Obtain the bed slope through the reach.

   c. Gather bed material samples by any of several approved methods.

   d. Sketch each cross-section in plan and profile and show important features, such as vegetation, approximate distances, and potential problem areas.

   e. Document the site with photographs.

   f. Where discharge data is not available, establish a control cross-section, where flow is most uniform. Survey the cross-section and take a discharge measurement. Take subsequent discharge measurements at lower and higher flows so that a stage-discharge relationship may be developed.

2. Analytical Investigations

   a. Gather discharge records and compile. (When records are not available, apply a suitable statistical or deterministic approach to the field data.) Plot hydrograph for each year and develop a characteristic discharge hydrograph.

b. Plot cross-section data and develop a stage-discharge (rating) curve using Manning's Equation; or develop the rating curve from discharge measurements made in the field.

c. From bed material samples, develop a gradation curve, or envelope of curves (as was done for Glacier Creek). Calculate D_m and determine D_{90} from the curve.

d. Using geometry of plotted cross-section, calculate for a wide range of water depths, q_B (bed-load rate), using the Meyer-Peter and Muller Equation, and multiply by w (top width of flow area) to obtain Q_s (bed load discharge).

e. Combine results of part (b), stage vs. discharge, with results of part (d), stage vs. bed load discharge, to develop discharge vs. bed load discharge.

f. Divide the recession portion of the typical hydrograph into straight line segments with short (10-day) time intervals. Obtain bed load rates for each end point by referring to the curve developed in part (e) and calculate recharge as:

$$\text{Recharge} = \sum(\Delta Q_s)(\Delta t)$$

Glacier Creek, TA-5

A preliminary recharge analysis was performed for Glacier Creek, in the vicinity of Girdwood Airport. The site is presently being utilized as a source for a limited amount of material. It appears to have the potential for considerably more utilization. As mentioned previously, this stream poses a high flood potential for the City of Girdwood, due in large part to its aggrading characteristics. Probably the single most effective means of combating the flood hazard is the optimization of mining activities to maintain the streambed at a constant elevation.

Field data obtained for the Glacier Creek site consisted of stream cross-sections, stream profile through the study reach, discharge measurements, and sampling of bed and bank material. The presence of a significant amount of very large material (4" - 12") causes problems in determining accurate gradations, as only a few such stones can have a biasing effect on the distribution of the overall sample. Therefore, in addition to the two material samples which were obtained, several different assumptions were made as to the percentage of this large material. An envelope of gradation values was developed, and representative material sizes were obtained from this envelope (see Figure III.7).

Bed load rate for flow depths of 1, 1.5, 2, 3, 4, 5, 6, and 7 feet were calculated using the Meyer-Peter and Muller Equation. Because the calculation of bed load rate is sensitive to bed material gradation, three values for Dm, effective grain diameter, were used: 20 mm, 40 mm, and 80 mm. (They are, respectively, the effective grain diameters using the lower limit, middle, and upper limit of the gradation envelope.) Table III.21 summarizes the calculations, and Figure III.8 shows them graphically.

Any plot of discharge vs. time will have rising limbs, representing increases in flow with time, followed by a peak, and a recession curve. Whenever flow increases, so does bed load discharge. More and more material is put into motion and moved downstream. The increasing velocities which accompany increasing flows will "scour" the stream bed to a certain degree, but as long as the bed load discharge capacity can be satisfied from upstream reaches, the amount of material lost to scour will be minimal, when compared to the total bed load discharge. As the flow decreases, the stream's ability to transport material is gradually lost, and less material is moved downstream. The result is recharge. The recharge of a stream depends not only on the flood magnitude, but also on the shape of the recession curve. A gradual decrease in flow will yield greater gravel deposits than would a short, abrupt change in flow.

Figure III.9 is a band of recession curves of the discharge hydrographs for Glacier Creek. It was developed from 12 years of record. The "upper limit" shows the shortest recession for the 12 years observed; and the "lower limit", the longest. It can also be noted that short recessions accompany higher peak flows than floods with long recessions. These extremes were coupled with extremes from Figure III.8 (Discharge vs. Bed Load Rate) to yield high and low recharge estimates for Glacier Creek of 400,000 tons/year and 2,000,000 tons/year.

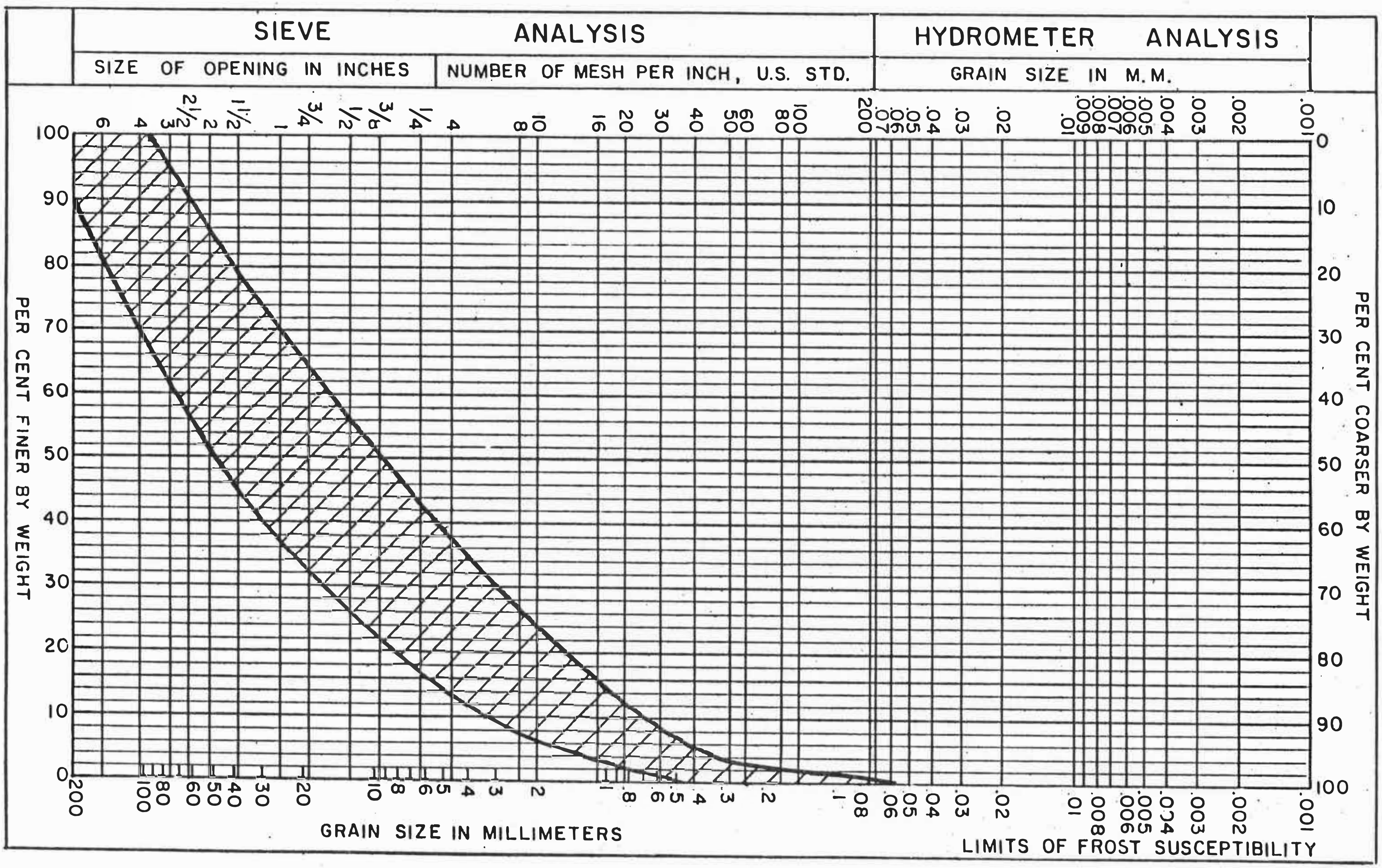


FIGURE III.7

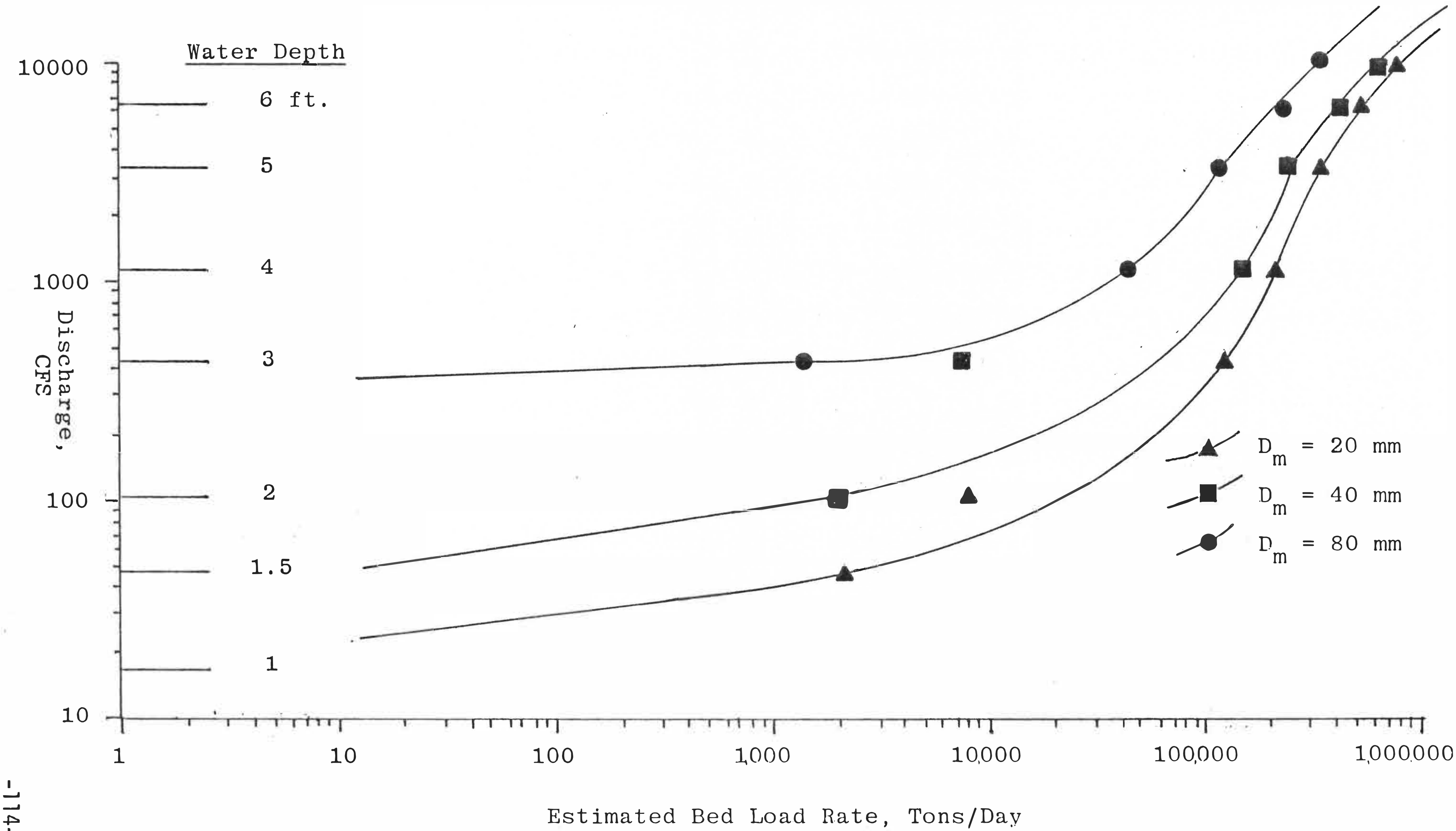
GLACIER CREEK ENVELOPE OF MATERIAL SIZES

TABLE III.21. Summary of Glacier Creek Bed Load Rate Calculations

Depth of Flow (ft)	Top Width of Flow Area (ft)	Q (cfs)	Bed Load Rate Dm = 20mm (tons/day)	Dm = 40mm (tons/day)	Dm = 80mm (tons/day)
1	9	17	0	0	0
1.5	33	45	2,250	0	0
2	52	105	8,100	2,081	0
3	330	420	132,000	75,000	1,500
4*	340	1,100	233,500	160,500	45,500
5	355	3,300	361,800	273,500	124,500
6	390	6,400	543,500	435,000	244,000
7	--	**	815,000	653,000	366,000

* Significant spreading of flow across floodplain begins about this depth.

** Major flooding begins. Out-of-bank flow.


Water Depth
6 ft.
5
4
3
2
1.5
1
10000
1000
100
10
Discharge, CFS
1
10
100
1,000
10,000
100,000
1,000,000
Estimated Bed Load Rate, Tons/Day
D_m = 20 mm
D_m = 40 mm
D_m = 80 mm

RECESSION CURVE ENVELOPE

OF GLACIER CREEK DISCHARGE HYDROGRAPHS

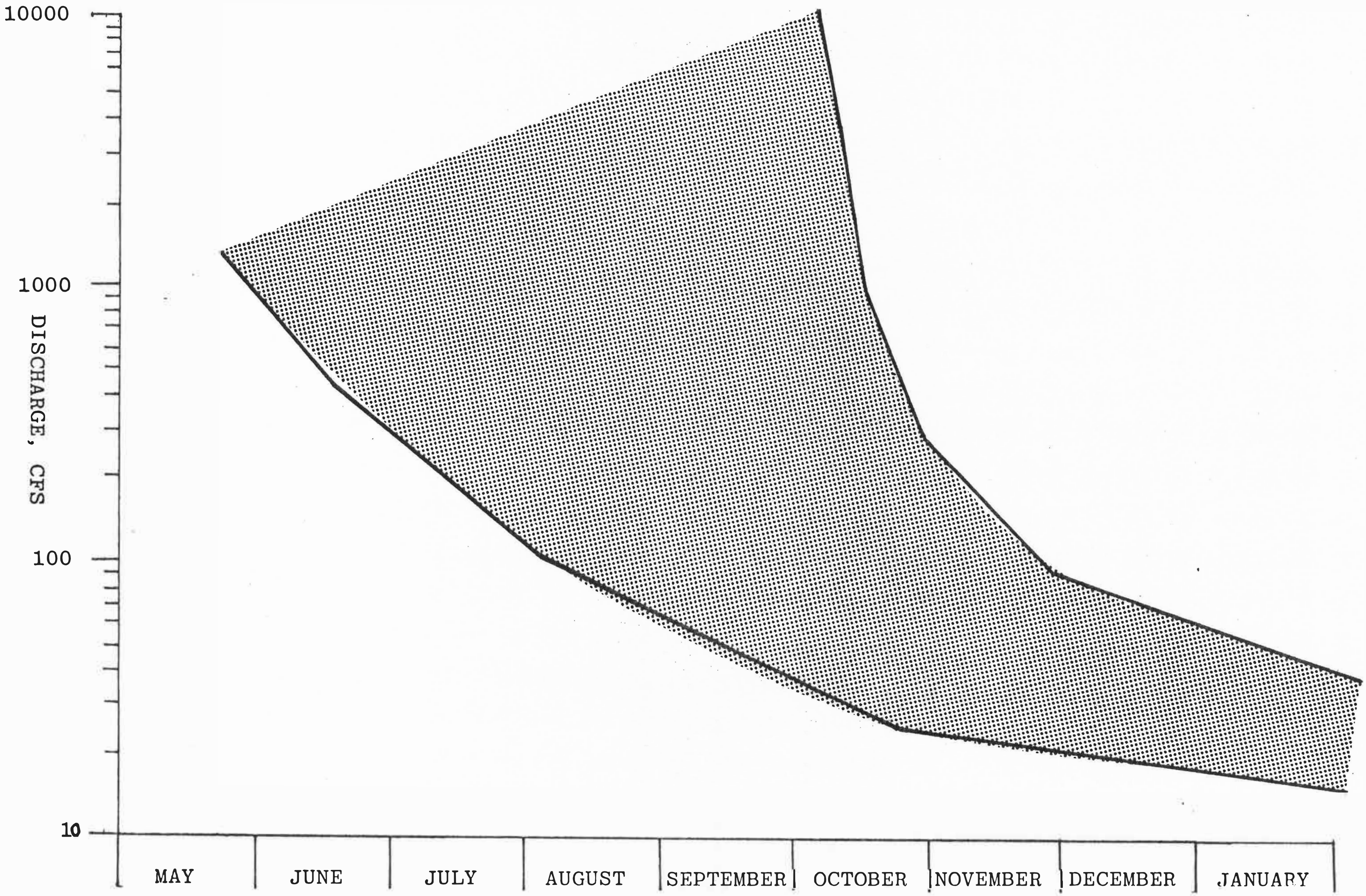


FIGURE III. 9

Eklutna River, ER-9

A detailed recharge analysis for the Eklutna River was not performed, despite the fact that it, like Glacier Creek, is a braided river, and somewhat aggrading. Our decision was based on the flowing points:

1. Determining flood magnitudes would have been extremely time consuming, as no recorded data exists.

2. Calculations (based on developed flow data) would indicate the capacity of the river to transport material. Actual recharge is limited, in this case, by the availability of material in the upstream reaches of the river.

3. The proposed Eklutna Water Supply Project would further limit the recharge capacity, since one portion of this project entails a diversion structure in the lower Eklutna River. This would effectively eliminate almost all recharge capability.

4. This site has been previously mined, but presently is inactive because extraction is not economical. This may be due to the politics involved (i.e., the Regional Native Corporation has subsurface property rights, even though the Village Native Corporation owns the land).

Although large quantities of material are present in the Eklutna River Floodplain, this material has accumulated over an extended period of time, with most of the depostion probably occurring prior to the construction of the Eklutna Dam. if the proposed water supply project is delayed or revised, some recharge capability will be retained, although it will be limited. In order to fulfill our contract obligations, and to illustrate orders of magnitude, we have performed representative recharge calculations using assumed stream parameters. It must be emphasized, however, that the results of these calculations should be applied with caution. It is our opinion that this site will not be dependable as a renewable source.

SAMPLE CALCULATION FOR GLACIER CREEK

In all calculations, it was assumed that:

D_{90} = 100 mm | w = 340 ft.

S = 1.10% | n_b = .035

For y = 4 ft. and D_m = 80 mm: | n_w = .050

$$\frac{Q_b}{Q} = \left[\frac{1}{1 + \left(\frac{2y}{w}\right)\left(\frac{n_b}{n_w}\right)^{3/2}}\right] = .986$$

Therefore:

$$q_b = 1.606 \left[3.306 \left(\frac{Q_b}{Q}\right)\left(\left(\frac{D_{90}}{n_b}\right)^{1/6}\right)^{3/2} yS - 0.627\ D_m\right]^{3/2}$$

$$= 1.606 \left[3.306\ (.986) \left[\frac{2.154}{.035}\right]^{3/2} (4)\ (.011) - .627\ (80)\right]^{3/2}$$

$$= 1.606 \left[69.267 - 50.160\right]^{3/2}$$

= 134 tons/day/foot of width

Total Recharge = (w) (q_b) = (340 ft.) (134 tons/day/ft.)

= 45,560 tons/day

SAMPLE CALCULATION FOR EKLUTNA RIVER

Assumptions

$S = .005$

$W = 200'$ (floodplain)

$n = .038$

$n_b = .035$

$n_w = .050$

$y_o = 4'$

$D_{qo} = 35$ mm

$D_m = 20$ mm

$$\left(\frac{Q_b}{Q}\right) = \frac{1}{1 + \frac{2 yo}{w}\left(\frac{n_w}{n_b}\right)^{3/2}} = \frac{1}{1 + \frac{(2)\ (4)}{200}\left(\frac{.050}{.035}\right)^{3/2}} = .9361$$

$$q_b = 1.606 \left[3.306 \left(\frac{Q_b}{Q}\right)\left(\frac{(D_{90})^{1/6}}{n_b}\right)^{3/2} yoS - 0.62\ D_m\right]^{3/2}$$

$$= 1.606 \left[3.306\ (.9361)\left(\frac{35^{1/6}}{.035}\right)^{3/2} (4)\ (.005) - 0.62\ (20)\right]^{3/2}$$

$$= 1.606 \left[23.03 - 12.40\right]^{3/2} = 56 \text{ tons/day/ft. width}$$

$$= 56(200) = 11{,}200 \text{ tons/day}$$

SUMMARY OF VALUES WITH VARYING RIVER STAGE *

Depth (ft.)	Recharge Capacity (tons/day)
1	0
2	0
3	2,600
4	11,200

* No field data obtained. All input data assumed.

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APPENDIX A

FIELD INVENTORY DATA FORMS

PIT NO. __________ DATE ____________________ FORM FILED BY ____________

LOCATION: _____________________________________ MOA PERMIT # ____________

____

____

NAME OF OPERATION _____________________________ PHONE # _________________

ADDRESS: _____________________________________

____

____

GROUND SLOPE CATEGORY: _____ 0-10% _____ 10-20% _____ 20-30%

_____ 35-45% _____ STEEPER

TYPE OF OPERATION: _____ STREAM BED SAND & GRAVEL MINING, _____ SAND & GRAVEL MINING ABOVE WATER TABLE, _____ SAND & GRAVEL MINING BELOW WATER TABLE, _____ WEATHERED BEDROCK MINING, _____ QUARRY STONE, _____ PEAT, _____ OTHER: (DESCRIBE) ____

____

____

GIVE SEC., TWN, RANGE (TO NEAREST 1/4, 1/4) ______________________________

____ GRID NO. __________

LAND OWNER(S) OF RECORD: ____

____

PROPERTY ZONED ____

_____ URBAN _____ SUBURBAN (R-7, I-3) _____ RURAL (R6, R8, R9, W, U)

DESCRIBE EXISTING SURROUNDING LAND USES WITHIN 1/2 MILE:

NORTH: ____

____

SOUTH: ____

____

EAST: ____

____

WEST: ____

____

PIT NO. ______________ DATE ____________________ FORM FILED BY: ______

DEVELOPING TREND IN GENERAL VICINITY: ____________________

____

____

ANTICIPATED ZONING CHANGES: ____________________

____

____

HOW LONG HAS PIT BEEN IN OPERATION? ____________________

TOTAL LAND AREA (EXCAVATED AND UNDISTURBED) ____________ ACRES

EXCAVATED AREA ______________ ACRES

UNDISTURBED AREA _____________ ACRES

ARE THERE ANY LANDS (NOT INCLUDED ABOVE) WHICH WILL BE USED FOR FUTURE EXPANSION? ____________________

IF YES, HOW MANY ACRES? ___________ ACRES. IF YES, WHERE IS IT LOCATED:

____

GRAVEL SALES FOR LAST FIVE YEARS (IN CUBIC YARDS):

1981 ____________________ COMMENTS: ____________________

1980 ____________________ ____________________

1979 ____________________ ____________________

1978 ____________________ ____________________

1977 ____________________ ____________________

INCLUDE BASIS OF FIGURES, NAME OF PERSON INTERVIEWED, OTHER PERTINENT DATA (USE ADDITIONAL SHEETS IF NECESSARY): ____________________

____

____

____

____

____

____

____

DESCRIBE ROUTE TO NEAREST COMMERCIAL STREET OR FREEWAY: ____________________

____

____

____

PIT NO. ____________ DATE ____________ FORM FILED BY____

PIT OWNERS (OR OPERATORS) ANALYSES OF HIS OPERATION: ____________

TRAFFIC & CIRCULATION: ACCESS ROAD CONDITIONS AND ANTICIPATED IMPROVEMENTS, IF ANY ____________

HOW MUCH TIME IS LEFT FOR OPERATION? ____________

HOW MUCH GRAVEL REMAINING AT CURRENT EXCAVATION RATE? ____________

WHAT WILL OWNER (OR OPERATOR) DO IF PIT IS EXHAUSTED? (SELL, REDEVELOP, ABANDON, ETC.) ____________

TO WHAT USE CAN LAND BE PUT WHEN PIT IS EXHAUSTED? ____________

IS THERE A CURRENT RECLAMATION PLAN? ____________

IS IT BEING IMPLEMENTED? ____________ DATE OF PLAN? ____________

IS PLAN APPROVED BY MOA? ____________ DATE: ____________

LIST EQUIPMENT (FIXED AND MOBILE) AT PLANT SITE (LOADERS, GRADERS, CRUSHING, CONCRETE/ASPHALT MIX PLANTS, ETC.): ____________

DESCRIBE EXISTING PIT (DEPTH BELOW SURROUNDING GRADE, EVIDENCE OF WATER TABLE, GLACIATION, THERMAL (FREEZE/THAW) EROSION, HOURS OF OPERATION, DUST, NOISE, DAILY TRAFFIC VOLUME, CONDITION OF WORKING AREAS, EXCAVATION SLOPES, ETC.) ____________

LIST EVIDENT VISUAL PROBLEMS (PROXIMITY TO SINGLE FAMILY, POOR STREETS, AESTHETICS, SCHOOLS, DUST, NOISE, ETC.) ____________

PIT NO. ________ DATE ________________ FORM F'''ED BY ____________

ANY COMMERCIAL PRODUCTS MANUFACTURED ON-SITE? (ASPHALT, CONCRETE, CEMENT BLOCKS, ETC.) ______________________________

TOTAL EMPLOYMENT: SUMMER ________ FULL TIME ONLY

WINTER ________ FULL TIME ONLY

DESCRIBE TYPE OF GRAVEL: ______________________________

IS SIEVE ANALYSIS AVAILABLE? ______ IF YES, ATTACH COPY

COMMENTS: ______________________________

NOTE:
1) TAKE AT LEAST TEN (1) COLORED SLIDES OF EACH SITE. (35mm)
2) HAND SKETCH DESCRIPTIONS WHENEVER POSSIBLE, AND/OR MARK POLAROID SX70 PHOTOS WITH A WATERPROOF PEN (SHARPIE).
3) COMPLETE AND ATTACH SPECIAL CHECKLISTS FOR WATER RESOURCES, GEOLOGY, AND GEOTECHNICAL CONSIDERATIONS AS APPLICABLE. FOR THE PURPOSE OF THIS INVESTIGATION, A STREAM SHALL CONSIST OF ANY SURFACE RUNNING WATER -- EVEN A TRIVIAL AMOUNT -- WHICH CARRIES WATER DURING ANY PART OF A YEAR.

GEOTECHNICAL ASSESSMENT

PIT NO. ____________ DATE ____________ FORM FILED BY: ____________

SEISMIC HAZARD ZONE: ____

COMMENTS: ____

____

EXISTING SLOPES, STABILITY: ____

____

RECOMMENDED MAXIMUM WORKING SLOPES: ____

____

RECOMMENDED MAXIMUM RESTORATION SLOPES: ____

____

RECOMMENDED MAXIMUM WORKING DEPTHS: ____

____

EXISTING HAZARDOUS CONDITIONS AND REMEDIAL MEASURES: ____________________

____

DETAILED INVESTIGATION NEEDED? _____ YES _____ NO

POTENTIAL MASS WASTING ZONE: ____

____

SNOWMELT AND DRAINAGE: ____

____

GLACIATION: ____

____

EROSION/SEDIMENTATION, AND RECOMMENDED REMEDIAL MEASURES: ____________

____

PERMAFROST (OR THAW UNSTABLE GROUND): ____

____

____

ANY ADDITIONAL COMMENTS: ____

____

____

____

GEOLOGIC REPORT

PIT NO. ________ DATE: ______________ FORM FILED BY ______

SEDIMENTARY ENVIRONMENT OF DEPOSITS, INCLUDING DESCRIPTION OF MAJOR GROUPS OF DEPOSITS, GRAIN SIZE RANGE, AND PERCENTAGE AMORPHOUS SILICA AND FRIABLE PARTICLES, BY VISUAL EXAMINATION:

DISTINCT GEOLOGIC FORMATIONS (CITE LITERATURE): ______________

STRUCTURAL GEOLOGY: ______________

PETROLOGY (IF APPLICABLE) - HAND SPECIMEN IDENTIFICATION ONLY; ALSO INCLUDE DEPTH AND SEVERITY OF WEATHERING, JOINTS AND ORIENTATION, FRACTURING, SLAB MOVEMENTS, AND OTHER PERTINENT LOCAL PHYSICAL AND CHEMICAL PROPERTIES:

SURFICIAL GEOLOGY; EROSION, DRAINAGE, AND LANDFORMS: ______________

ANY ADDITIONAL COMMENTS: ______________

WATER RESOURCES, HYDROLOGY, HYDRAULICS

PIT NO. ____________ DATE ________________ FORM FILED BY ____________

STREAM(S) AFFECTED BY THIS MINING OPERATION:

______________________________, WATERSHED ________________________

______________________________, WATERSHED ________________________

______________________________, WATERSHED ________________________

DESCRIBE EACH STREAM: ____

____

____

ESTIMATED NORMAL FLOW RATE _____________ WINTER ____________ SUMMER (CFS)

EXISTING CHANNEL CONDITION: FLOOD PLAIN ___________________________

________________________ ______________________________________

________________________ ______________________________________

________________________ MAX. FLOOD STAGE (FLOW) _______________

________________________ SOURCE _______________________________

WINTER CHANNEL CONDITIONS, ICING LIMITS ______________________________

____

____

____

CULVERTS AND BRIDGES WITHIN AND DOWNSTREAM OF MINING OPERATIONS _________

____

____

____

IMPACTS ON STREAM RESULTING FROM THIS MINING OPERATION - CHECK FOLLOWING:

_____ DIVERSION(S) _____ DAM(S) _____ EFFLUENT DISCHARGE(S)

_____ SEDIMENTATION _____ EROSION _____ FLOOD PLAIN EXCAVATION

_____ EXCAVATION WITHIN STREAM BANK

REMARKS: (COMPATIBILITY WITH ANCHORAGE 208 WATER QUALITY MANAGEMENT PLAN)

____

____

____

____

ATTACH GRAVEL RECHARGE RATE CALCULATIONS

APPENDIX B

INDEX TO PHOTOGRAPHS AND SLIDES

INDEX TO PHOTOGRAPHS AND SLIDES

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APPENDIX C

STATE OF ALASKA MEMORANDUM

MEMORANDUM

State of Alaska

TO: Tommie Hendrick
Aviation Design Engineer

DATE: June 8, 1982

FILE NO: 242C-2918

TELEPHONE NO: 266-1502

FROM: Donald D. Morfield
Highways Design Engineer
Central Region

SUBJECT: Gravel Needs From Airport Materials Sites

In accordance with our previous conversations and exchange of information, this will confirm our (Highways) estimated needs for gravel materials close to Anchorage International Airport:

1.	Dimond Boulevard -	350,000 C.Y.	1984, 85, 86
2.	Raspberry Road -	30,000 C.Y.	1985
3.	Minnesota Drive, Phase II -	250,000 C.Y.	1985 - 1986 - 1987
4.	Minnesota-International Interchange -	300,000 C.Y.	1985
5.	O'Malley Interchange -	300,000 C.Y.	1987
~~6.~~	~~International Airport Bypass -~~	~~200,000 C.Y.~~	
7.	C Street 4 Lane -	150,000 C.Y.	1983 → 1984 → 1985 → 198[illegible]
8.	C Street Interchange -	200,000 C.Y.	
	TOTAL -	1,780,000 C.Y.	
	Boniface Interchange	100,000	1984
	Old Seward Dimond → Dowling	50,000 CY	1984
	~~C St. [illegible] to Dimond~~		
	Boniface Debarr → Tudor	50,000	198[illegible]

DBM/bpa

APPENDIX D

FULL DEPTH AND GRANULAR BASE COURSE DESIGN FOR FROST AREAS

Full-Depth and Granular Base Course Design for Frost Areas

By Robert A. Eaton,[1] and James O. Payne, Jr.[2]

(Reviewed by the Highway Division)

Abstract: When properly designed and constructed, the Asphalt Institute full-depth pavement concept can be a viable design alternative for seasonal frost areas. The Corps of Engineers reduced subgrade strength frost design proved to be an upper bound or conservative design under these test conditions. For each design, two different thicknesses were studied in test sections placed over 12 in. of prepared subgrade and tested under light traffic conditions in Hanover, New Hampshire. After design traffic loading was exceeded, pavement failure occurred as expected in the thinner full-depth section. The thinner reduced subgrade strength section was still in good condition after experiencing twice its design loading. Frost penetrations, pavement *n*-factors (surface transfer coefficients), Benkelman Beam deflections, and the spring subgrade moisture contents are also compared for the two designs.

Introduction

In the late 1960s, the Office, Chief of Engineers (OCE), of the Corps of Engineers (CoE) received numerous inquiries concerning highway pavement frost designs from its district and division offices. These offices were requesting OCE to relax their frost design thickness criteria. In one case, a 26-in. (660-mm) thick cross section on a federal military reservation was met at the front gate by a 14 in. (360 mm) cross section designed by the state.

The OCE directed the CoE United States Army Cold Regions Research and Engineering Laboratory (USACRREL) in Hanover, New Hampshire, to evaluate the Corps pavement frost design criteria and determine what effect thickness reductions would have on pavement performance.

The Asphalt Institute (TAI) at that time was promoting the "full-depth" design concept. The term full-depth, as used in this report, is defined in The Asphalt Institute Manual Series No. 5 (3) and is registered by TAI with the U.S. Patent Office. The definition of a full-depth pavement is "a pavement in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade. A full-depth asphalt pavement is laid directly on the prepared subgrade."

Test sections were constructed in 1971 to compare the Corps of Engineers reduced subgrade strength design with The Asphalt Institute full-depth design

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Note.—Discussion open until June 1, 1982. To extend the closing date one month, a written request must be filed with the Manager of Technical and Professional Publications, ASCE. Manuscript was submitted for review for possible publication on November 21, 1980. This paper is part of the Transportation Engineering Journal of ASCE, Proceedings of the American Society of Civil Engineers, ©ASCE, Vol. 108, No. TE1, January, 1982. ISSN 0569-7891/82/0001-0027/$01.00.

under freeze-thaw conditions. This paper presents the results of seven years of field tests and continuous site observation.

Site Conditions and Test Sections

The test sections were built on an access road to a gravel pit on the north side of the USACRREL facility in Hanover, New Hampshire. The climate is subcontinental, or woodland, in the cool temperate zone (11).

Freezing Indices.—The design freezing index for Hanover is 1,820° F-days (1,011° C-days). This index is based on the average of the three coldest years in thirty. The mean freezing index is 1,060° F-days (589° C-days), as determined by Gilman (10).

Subgrade Soil.—The natural subgrade soil in the test area is a nonplastic frost-susceptible silt, classified as ML under the Unified Soil Classification System (7) and as F-4 under the Corps of Engineers frost group classification (5). The "normal period" California Bearing Ratio (CBR) value, i.e., "summer strength" CBR, was eight based upon field tests. The in-situ moisture content of the silt, based on the dry unit weight, ranged from 25%–35% prior to construction. The optimum moisture content of the material is 13%, as shown in Fig. 1, for the CE-55 compaction test (similar to American Association of State Highway and Transportation Officials (AASHTO) T180-74, Method B).

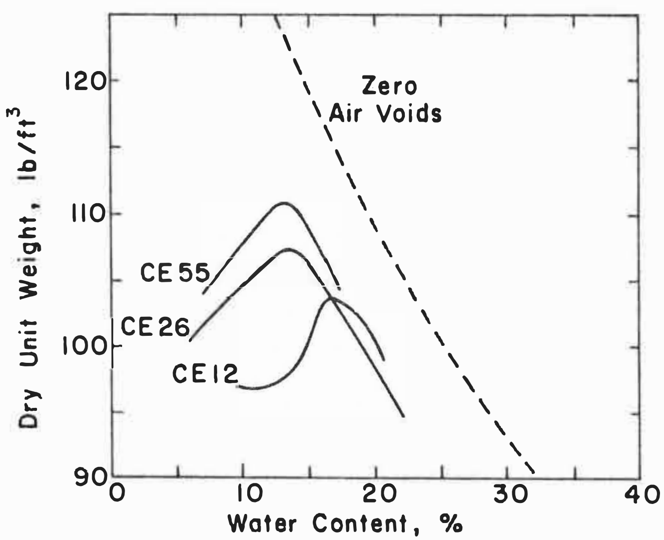

FIG. 1.—Laboratory Moisture-Density Curve

Test Sections Design.—Each section was 24 ft (7.3 m) wide × 50 ft (15.3 m) long (Fig. 2). The top 12 in. (300 mm) of the subgrade was scarified and mixed to ensure uniform conditions (9).

A stated objective of the project was to test a "heavy" and "light" traffic load for each design over a 20-yr design life with zero traffic growth.

Sections 1 and 3 were designed on the basis of an average daily traffic load of 4,000 vehicles (total for both directions) on a two-lane rural highway.

Sections 2 and 4 were designed on the basis of an average daily traffic load of 100 vehicles (total for both directions) on a two-lane rural highway.

Using the Corps of Engineers criteria for reduced subgrade strength design (5) resulted in combined thicknesses for pavement, crushed stone base, and sand filter layer of 30 in. (760 mm) and 22 in. (560 mm) for Sections 1 and 2, respectively (Fig. 3).

Sections 3 and 4 were designed using full-depth pavement design criteria (3) for a subgrade CBR value of eight, which resulted in thicknesses of 9 and 5 in. (230 and 130 mm), respectively (Fig. 3).

Instrumentation and Tests

Temperature of Pavement, Base, and Subgrade.—Copper constantan thermocouples were installed at the center of each section to a depth of 5 ft (1.5 m) to monitor the rate of frost penetration and recession, maximum depth of frost penetration, freeze-thaw cycles, and isotherm locations. Fig. 2 is a plan view showing the location of the thermocouples. The cross-sectional view in Fig. 3 shows their depths beneath the surface.

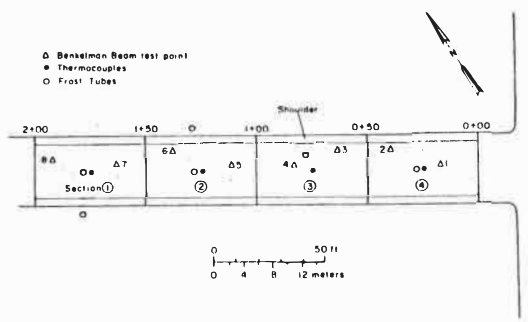

FIG. 2.—Instrumentation Locations

Frost Penetration.—Methyl blue/water frost tubes were installed in each of the four sections to compare the frost penetration measurements with the thermocouple readings (13). Their locations are also shown in Fig. 2.

Moisture Changes.—Subsurface moisture measurements were made in 10-ft (3-m) deep steel access tubes located on centerline with a 3-ft (910-mm) offset from the midpoint of each section. A Nuclear-Chicago Model 5810 subsurface nuclear moisture probe and a Nuclear-Chicago Model 5920 d/M gage scalar were used to measure moisture content variations during the first four years.

Surface Deflection.—The Benkelman Beam test (2) gives an indication of pavement strength. Two Benkelman Beam Test points per section (a total of eight points) were used to measure pavement strength characteristics (Fig. 2). The vehicle used for the test was a two-axle truck equipped with dual-tired wheels, each loaded to 9,000 lb (4,082 kg) ±100 lb (45 kg) for a total rear axle load of 18,000 lb (8,164 kg) ±200 lb (90.7 kg).

Frost Heave.—Level surveys were taken on 139 elevation checkpoints with various engineer levels with an accuracy of ±0.01 ft at least once a month to monitor frost heave and permanent set. A 10-ft (3-m) deep manhole was used as the frost-free benchmark.

Climatology.—Air temperatures and other weather observations were made at a field site located about 1,000 ft (305 m) west of the road at an elevation about 20 ft (6.1 m) lower. The U.S. Army Maynard Meteorological Team, Sudbury, Massachusetts, took the observations and provided monthly tabulated summaries.

Test Results and Analysis

Freezing Index.—The freezing index decreased each of the first four years from 1,430° F-days (794° C-days) in 1971–72 to a low of 955° F-days (531° C-days) in 1974–75, indicating milder freezing seasons each year. The following three years had above average freezing seasons with freezing indices above 1,400° F-days (778° C-days), compared to a mean index of 1,060° F-days (589° C-days) for Hanover, New Hampshire.

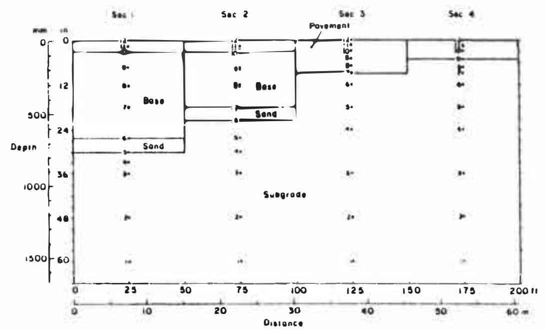

FIG. 3.—Thermocouple Locations

Frost Penetration.—The subsurface temperatures during the latter part of the freezing seasons and the entire spring thaw periods were examined hourly. Maximum frost penetrations beneath the sections are shown in Table 1 for each of the seven winters.

The test sections were maintained as a normal highway section and kept essentially free of ice and snow throughout the winter seasons.

Temperature fluctuations, both diurnal and those caused by changing weather systems, subjected the upper 18 in. (460 mm) of the pavement structures to numerous freeze-thaw cycles (Fig. 4). After freezing temperatures had penetrated to greater depths, where daily variations were attenuated, the materials at those depths remained in a frozen state until spring thaw. The reduced subgrade strength sections consistently had deeper frost penetration than the full-depth sections. Because the moisture content of the crushed stone base was less than that of the silt subgrade directly beneath the full-depth pavement, the reduced subgrade strength sections were able to freeze at a faster rate, and therefore, deeper.

Pavement Freezing Indices.—Average daily temperatures on pavement surfaces in Sections 2, 3, and 4 for 1973–78 were used to calculate actual surface freezing indices, which in turn were used to calculate *n*-factors for both the winter season and the month-by-month breakdown. The Section 1 surface thermocouple was inoperative; therefore, that section was not included in the *n*-factor calculations. The *n*-factor is an empirically based correction factor in the "modified" Berggren formula for the calculation of depth of freeze beneath highway and airfield pavements which serves to convert air freezing data to ground surface temperature (4).

The *n*-factors are shown in Table 2. They vary from 48%–78% of the 0.9 worldwide average winter value recommended by the Department of the Army for the design of pavements free of ice and snow (4).

The full-depth sections had consistently lower *n*-factors due to the warmer pavement. This was caused by a slower rate and shallower depth of freezing under the full-depth sections than in the reduced subgrade strength sections. The full-depth sections were placed directly upon high moisture content silt which took longer to freeze than the crushed rock base course beneath the reduced subgrade strength sections.

TABLE 1.—Maximum Frost Penetration, in inches

Variable (1)	Year 1971–1972 (2)	1972–1973 (3)	1973–1974 (4)	1974–1975 (5)	1975–1976 (6)	1976–1977 (7)	1977–1978 (8)
Freezing Index, in degree-days, Fahrenheit (Celsius)	1,430 794	1,143 635	1,021 567	955 531	1,408 782	1,636 909	1,513 840
Section:							
4 (5 in.)	36–40	30–36	36	32	36	41	32
3 (9 in.)	40–44	30–36	37	31	36	41	29
2 (22 in.)	36–40	30–36	35	30	—	41	34
1 (30 in.)	36–40	30–36	38	35	43	43	42

Note: 1 in. = 25.4 mm.

Variation in Subsurface Moisture.—The nuclear moisture probe measured water content by volume in a sphere approx 2 ft (610 mm) in diameter, depending on soil density, organic content, and water content.

The nuclear probe source appeared to be defective in August, 1972, and had to be repaired. The probe was returned with a new radioactive source in February, 1973, which resulted in higher moisture readings. Difficulties with snow and ice removal on the test sections prevented ready access to the tubes and limited the number of tests conducted in the spring of 1973.

Plots of the relative values of moisture data obtained are shown in Figs. 5(*a*)–(*d*), as neither source was calibrated for absolute values. The concern was to measure moisture changes, not absolute moisture contents.

The crushed stone base course and sand layer in sections 1 and 2 had a range in moisture contents between 4% and 16% by volume from 1972–1977 which is within the normal range of moisture content. The fine-grained silt subgrade beneath the full-depth sections at the same depth as the gravel and sand in the Corps sections had moisture contents ranging from 26%–56%. The moisture contents of the silt subgrade were relatively the same beneath all sections at equal depths.

These data also showed dramatic moisture content increases of 10%–15% by volume in the top 24 in. (610 mm) of the full-depth sections during the critical spring thaw weakening period. As thaw progressed downward, the saturated, thawed subgrade was trapped between the full-depth pavement and the frozen subgrade below, resulting in very high Benkelman Beam deflections in the 5-in. (130-mm) full-depth section. However, the 9-in. (230-mm) full-depth section was strong enough to distribute the load evenly.

The crushed stone base courses retained their structural strength during spring

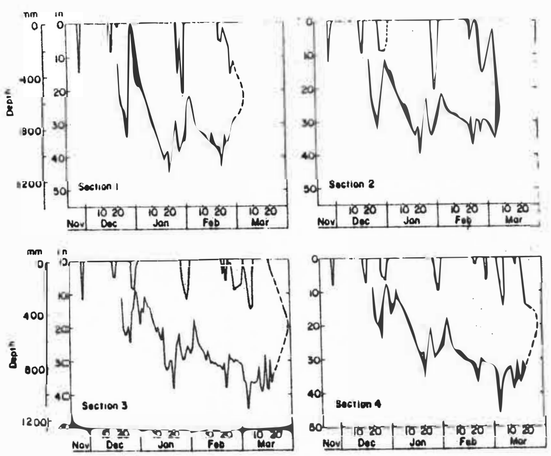

FIG. 4.—1973-1974 Frost Penetration (32° F (0° C) isotherms)

thaw weakening by not permitting as much moisture to collect, or frost heave to occur, as in the subgrade silt.

Frost Heave.—The average maximum frost heaves for each section for all seven years are shown in Table 3.

The full-depth sections' (3 and 4) maximum heaves varied from a low of 2 in. (51 mm) in 1974–75 to a high of 3.5 in. (89 mm) in 1977–78.

The thinner gravel base course section 2 heaved from 0.5 in. (13 mm) in 1974–75 to a maximum of 2 in. (50 mm) in 1977–78.

The thicker gravel base course section (1) heaved from a low of 0.2 in. (5 mm) in 1974–75 to a high of 1.25 in. (32 mm) in 1977–78.

Pavement Deflection Measurements.—Pavement temperature can influence the pavement stiffness and thus affect the Benkelman Beam test results. A common standard temperature that Benkelman Beam measurements are corrected to is +70° F (21° C). Various agencies have their own methods (i.e., curves, factors, etc.) for modifying the readings to the standard temperature. To date, a method for standardizing results at temperatures below +35° F (1.7° C) has not been established; therefore, these data have not been modified.

The results of the Benkelman beam static pavement rebound deflection tests are summarized in Table 4.

The static pavement rebound deflections represent measurements taken in the outer vehicular wheel paths (points 2, 3, 6, and 8) of each section (Fig. 2). The measured deflections at the inner wheel paths generally followed similar trends and ranges of deflection as the outer wheel paths.

When the freezing index was less than 1,200° F-days (667° C-days), the section with the least deflection (strongest) was the thickest of the sections (1), followed by section 2, section 3, and section 4, respectively. Section 4 had two to four times greater deflection than the other three sections, with deflections of up to 0.1700 in. (4.32 mm).

When the freezing index was greater than 1,400° F-days (778° C-days), the 22-in. (560-mm) section (2) was strongest, followed very closely by the 9-in. (230-mm) and 30-in. (760-mm) sections (3 and 1). The 5-in. (130-mm) section had three to four times greater deflection—up to 0.1750 in. (4.45 mm).

TABLE 2.—Surface "*n*-Factors" and Ratios

Year (1)	Section (2)	*n*-Factors (3)	Surface Ratios: December (4)	January (5)	February (6)	March (7)
1973–74	2	606/1,021 = 0.59	70/192 = 0.36	313/370 = 0.84	334/392 = 0.57	—
	3	431/1,021 = 0.42	46/192 = 0.24	206/370 = 0.56	179/392 = 0.46	—
	4	448/1,021 = 0.43	44/192 = 0.23	209/370 = 0.56	194/392 = 0.48	—
1974–75	2	584/955 = 0.61	95/100 = 0.95	260/317 = 0.82	219/331 = 0.66	—
	3	451/955 = 0.47	67/100 = 0.67	205/317 = 0.65	179/331 = 0.54	—
1976–77	2	1,142/1,636 = 0.70	420/515 = 0.82	500/727 = 0.69	205/335 = 0.61	—
	3	957/1,636 = 0.58	309/515 = 0.60	441/727 = 0.61	207/335 = 0.62	—
	4	934/1,636 = 0.57	304/515 = 0.59	444/727 = 0.61	169/335 = 0.50	—
1977–78	2	831/1,513 = 0.55	191/300 = 0.64	285/509 = 0.56	288/532 = 0.54	66/172 = 0.38
	3	680/1,513 = 0.45	127/300 = 0.42	229/509 = 0.45	258/532 = 0.48	66/172 = 0.38
	4	733/1,513 = 0.49	119/300 = 0.40	253/509 = 0.50	274/532 = 0.52	88/172 = 0.51

Average deflections for the 30-, 22-, and 9-in. (760-, 560-, and 230-mm) sections were within 0.009 in. (0.23 mm) of each other for six of the seven years. The difference between the same three sections for the coldest of the seven winters (1976–77) was 0.022 in. (0.56 mm).

The 5-in. (130-mm) section was weakest with the seven-year average maximum deflections 3.2 times greater than the other three sections.

Seven year average maximum deflections were:

1. Section 1: 0.0346 in. (0.88 mm).
2. Section 2: 0.0322 in. (0.82 mm).
3. Section 3: 0.0371 in. (0.94 mm).
4. Section 4: 0.1171 in. (2.97 mm).

Benkelman beam deflections show that, on the average, the 9-in. (230-mm) full-depth section and the 22- and 30-in. (56- and 760-mm) granular base course sections deflected about the same amount. On the other hand, the 5-in. (130-mm) full-depth section was over three times weaker than the others.

Traffic.—Serving as an access road to a town gravel pit, the sections carried truck traffic during the critical spring thawing period. The daily traffic intensity assumed for design was not expected to be reached.

As an illustration of a typical spring, on March 20, 1972, trucks began hauling gravel out of the pit, and by April 6, 2,000 vehicles had traversed the sections (approx 47% were loaded gravel trucks). The heaviest traffic during this period occurred on April 3 and consisted of 75 loaded gravel trucks, 75 unloaded trucks, and one auto. Two loaded trucks were stopped and weighed on portable weighing scales on April 4 with the following measured results:

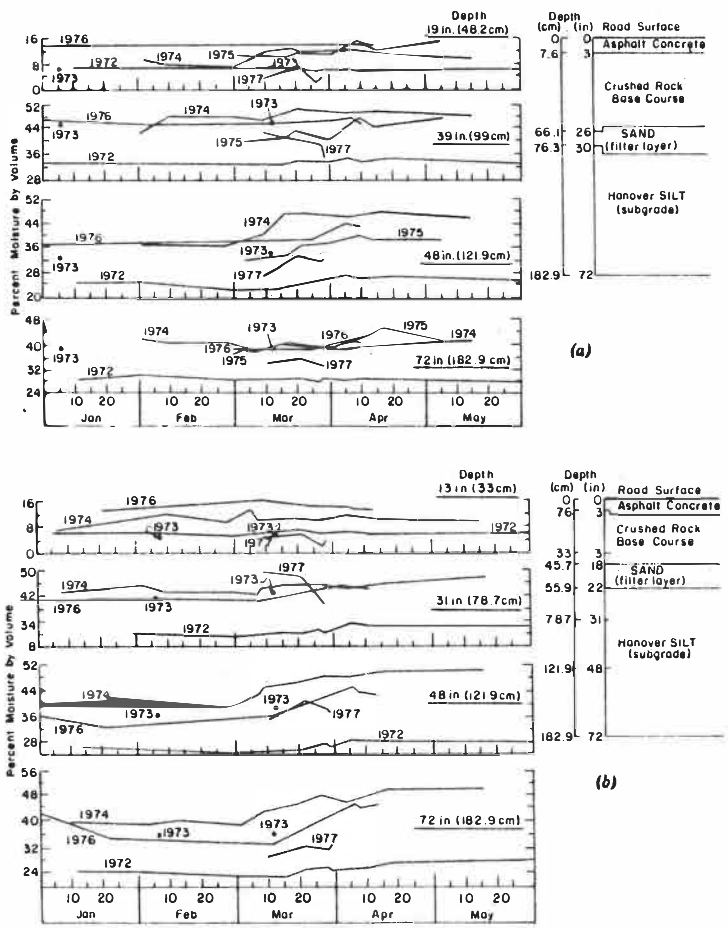

FIG. 5.—(a) Nuclear Moisture Measurements. Section 1; (b) Nuclear Moisture Measurements. Section 2

Vehicle	Gross Weight	Rear Axle Weight
No. 1	30,275 lb (13,732 kg)	22,000 lb (998 kg)
No. 2	29,150 lb (13,222 kg)	21,275 lb (965 kg)

The two trucks weighed were typical of the type and load capacity of all trucks traversing the test section.

Equivalent Operations Factors from TM 5-330 (6) for equivalent 18-kip (8,165-kg) axle loads are 2.4 for 22-kip (9,979 kg) single-axle trucks (loaded

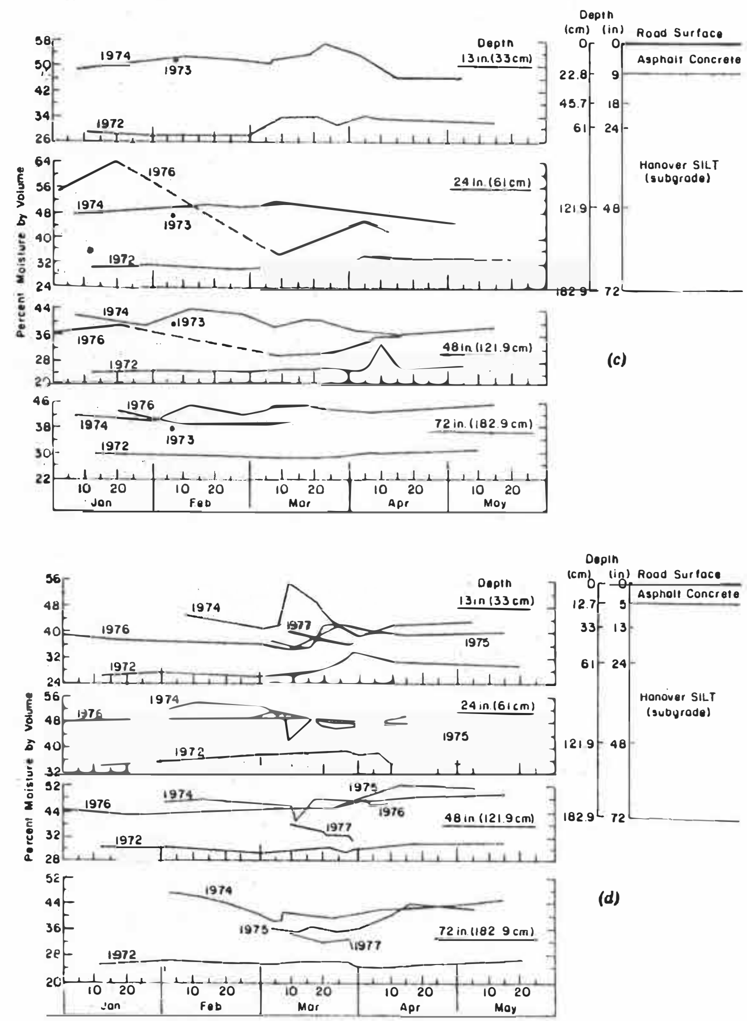

FIG. 5.—(c) Nuclear Moisture Measurements. Section 3; (d) Nuclear Moisture Measurements. Section 4

gravel trucks), 0.04 for 15-kip (6,304-kg) single-axle trucks (empty gravel trucks), and 0.002 for cars.

Based upon the April 4 traffic count, sections 2 and 4 were subjected to daily load repetitions exceeding their design premise of 3 equivalent 18,000-lb (8,165-kg) axle loads per day. Even so, the total number of passes of loaded trucks during the 1972 thawing period was only a small fraction of the product of the daily loadings assumed for design and the number of critical days of subgrade thawing that might be expected in the twenty year design period. On Sections 1 and 3, the truck traffic experienced in the spring of 1972 was

TABLE 3.—Average Maximum Frost Heave, in inches

Year (1)	Section 1 (2)	Section 2 (3)	Section 3 (4)	Section 4 (5)
1971–72	0.56	1.24	2.50	2.76
1972–73	0.44	0.82	2.45	2.49
1973–74	0.32	0.57	2.34	2.14
1974–75	0.20	0.71	1.85	2.37
1975–76	0.82	1.49	2.58	2.87
1976–77	1.22	1.95	3.22	3.13
1977–78	1.07	1.82	3.39	3.41

Note: 1 in. = 25.4 mm.

TABLE 4.—Maximum Benkelman Beam Deflections, in inches

Variable (1)	Year 1971–72 (2)	1972–73 (3)	1973–74 (4)	1974–75 (5)	1975–76 (6)	1976–77 (7)	1977–78 (8)
Freezing Index, in degree-days, Fahrenheit (Celsius)	1,430 794	1,143 635	1,021 567	955 531	1,408 782	1,636 909	1,513 840
Section 4:							
0 + 11, in feet	0.0550	0.1150	0.1210	0.0584	0.1320	0.1750	0.1310
0 + 38	0.0830	0.0955	0.1700	0.0848	0.1140	0.1480	0.1470
Average	0.0690	0.1053	0.1455	0.0716	0.1230	0.1615	0.1390
Section 3:							
0 + 61	0.0285	0.0280	0.0410	0.0345	0.0450	0.0625	0.0350
0 + 89	0.0200	0.0240	0.0310	0.0360	0.0400	0.0630	0.0305
Average	0.0243	0.0260	0.0360	0.0353	0.0425	0.0628	0.0328
Section 2:							
1 + 11	0.0270	0.0330	0.0350	0.0310	0.0380	0.0480	0.0360
1 + 38	0.0240	0.0250	0.0300	0.0283	0.0305	0.0325	0.0320
Average	0.0255	0.0290	0.0325	0.0297	0.0343	0.0403	0.0340
Section 1:							
1 + 61	0.0270	0.0270	0.0260	0.0305	0.0460	0.0640	0.0320
1 + 89	0.0275	0.0250	0.0280	0.0304	0.0410	0.0520	0.0285
Average	0.0273	0.0260	0.0270	0.0305	0.0435	0.0580	0.0303

Note: 1 in. = 25.4 mm.

insignificant compared to the design premise of 100 equivalent 18,000-lb (8,165-kg) axle loads per day.

Slight rutting was visible in the wheel tracks in Section 3 and 4 during the

heavy traffic period, with the depressions particularly noticeable in Section 4. After loading stopped (April 6, 1972) the pavement recovered its even surface.

During the eight-year period, over 97,000 vehicles passed over the sections, resulting in 44,700 equivalent 18-kip (1,865-kg) axle loads. Table 5 gives the total equivalent 18-kip (1,865-kg) axle loads that crossed the test sections from September, 1971, to June, 1979. The traffic counter broke in March, 1977, and after that time the count was estimated by a USACRREL technician.

Sections 2 and 4 were designed to carry three equivalent 18-kip (8,165-kg) axle loads per day for 20 yr, for a total of 21,900 equivalent 18-kip (8,165-kg) axle loads. The design life was reached for these sections between June, 1975, and May, 1976.

Sections 1 and 3 were designed to carry 100 equivalent 18-kip (8,165-kg) axle loads per day for 20 yr, for a total of 299,181 equivalent 18-kip (8,165-kg) axle loads. In eight years, only 44,713 equivalent 18-kip (8,165-kg) axle loads had traversed these sections. The design life was not reached.

TABLE 5.—Total Equivalent 18-kip Axle Loads Traversing Test Sections

Vehicle (1)	Equivalency factor (2)	Number of Vehicles: Sept. '71–Mar. '77 (3)	Mar. '77–June '79[a] (4)	Total (5)
Loaded single axle truck	2.4	13,775	4,500	18,275
Unloaded single axle truck	0.04	13,775	4,500	18,275
Car	0.002	55,758	5,000	60,758
				97,308

[a]Estimated—traffic counter broke in March, 1977.

Note: Calculations.

2.4(18,275) = 43,860
0.04(18,275) = 731
0.002(60,758) = 122

44,713 total equivalent 18-kip axle loads.

The 5-in. (130-mm) full-depth section did meet its design life of 21,900 equivalent 18-kip (1,865-kg) axle loads, but failed soon after during the 1975 spring thaw, when severe load cracking and wheel rutting occurred. Some cracking resulted when test cores taken from the pavement caused localized weak areas. Although substantial load (alligator) cracking has occurred since the spring of 1975, the section is still serviceable and does carry traffic.

The 22-in. (560-mm) Corps of Engineers section met its design life of 21,900 equivalent 18-kip (8,165-kg) axle loads in 1975 and has continued to carry more than 44,700 equivalent 1-kip (8,165-kg) axle loads with no failure.

The 9-in. (230-mm) full-depth and 30-in. (760-mm) Corps of Engineers sections have not failed, and are not expected to fail for another 50 yr under the current traffic load.

Thermal cracks caused by core holes have occurred in all sections.

Summary.—The seven-year analysis of the sections show that:

1. The freezing index during the seven-year study ranged from a low of 955° F-days (531° C-days) in 1975–76 to a high of 1,635° F-days (908° C-days) in 1976–77, with a mean of 1,301° F-days (722° C-days). The design freezing index for Hanover, N.H., is 1,820° F-days (1,011° C-days) and the mean is 1,060° F-days (589° C-days).

2. Frost penetration was nearly the same in both the 5- and 9-in. (130- and 230-mm) full-depth sections. Frost penetration was slightly deeper in the reduced subgrade strength sections, with the 30-in. (760-mm) section being deeper than the 22-in. (560-mm) section.

3. The pavement n-factors (surface transfer coefficients) were lower for the full-depth design sections than the Corps design sections, indicating higher pavement surface temperature in the full-depth sections.

4. Moisture increases beneath the full-depth sections during the freeze-thaw period caused high springtime Benkelman Beam deflections. Visible transitory rutting in the wheel tracks also resulted, due to heavy truck loading. Moisture increases averaged 10%–15% by volume each year in the 2 ft (610 mm) of subgrade directly beneath the full-depth sections.

5. Frost heave was fairly uniform, with the full-depth sections averaging approx 2.5 in. (64 mm) of heave during the first four years. Full-depth heaves of 2.5–3.5 in. (64–89 mm) occurred the last three years. The reduced subgrade sections heaved less than an inch (25 mm) for four years and averaged between 1 and 2 in. (25–51 mm) the last three years. Although the heaves were greater in the full-depth sections, they were relatively uniform and did not produce noticeable roughness. This uniformity in heaving is attributed to the subgrade preparation, which involved the scarifying, blending and recompaction of the top 12 in. (300 mm) of the in-situ silt subgrade soil.

6. The 9-in. (230-mm) full-depth section Benkelman Beam deflections were, on the average, the same as the deflections on the two reduced subgrade strength sections of 22- and 30-in. (560- and 760-mm) thick gravel base course. The 5-in. (130-mm) full-depth section deflections, however, were three to four times greater than on the other three sections.

7. Traffic has been light but the design has been exceeded for the 5-in. (130-mm) full-depth and 22-in. (560-mm) Corps of Engineers reduced subgrade strength sections. The 5-in. (130-mm) section "failed" soon after its design traffic loading was exceeded. The section has a depressed area, is severely cracked, and deflects considerably; but has not potholed and remains in service. The 22-in. (560-mm) section has experienced twice its design loading and is still in good condition. The 30-in. (760-mm) Corps section and 9-in. (230-mm) full-depth sections have received approximately one-sixth of their design loading and are in good condition. Minor surface and thermal contraction cracking has occurred in all sections.

Conclusions

Results of the seven-year study comparing the reduced subgrade strength design with the full-depth design lead to two preliminary conclusions:

1. The Asphalt Institute full-depth highway pavement design can be a viable alternative in seasonal frost areas when properly designed and constructed upon a properly prepared subgrade.

2. The Corps of Engineers reduced subgrade strength highway pavement frost design was found to be an upper bound or conservative design for these test conditions.

Further controlled traffic and field testing is recommended to revise the Corps of Engineers reduced subgrade strength design for highway pavements in seasonal frost areas.

Acknowledgment

This research was carried out at the Corps of Engineers Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire, under Department of the Army Project 4K078012AAM1. The authors would like to thank technical reviewers E. Lobacz, N. Smith, D. Gaskin, D. Moon, and all other CRREL personnel who provided valuable assistance during this seven year study.

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APPENDIX E

IOPNET - PROGRAM DESCRIPTION AND ACCESS GUIDE

IOPNET - PROGRAM DESCRIPTION AND ACCESS GUIDE

(In Core / Out of Core Network Flow Algorithm)

Boeing Computer Services, Energy Technology Applications Division, P.O. Box 24346, Seattle, Washington 98124, (206) 575-5085

Description

IOPNET is a mathematical programming system on MAINSTREAM-EKS for solving network flow problems. Typical networks involve assignment, transportation, transshipment, shortest path and maximum flow models. These problems arise from having to transport a given quantity of manpower or material from the point (nodes) to another point over a specific path (arcs). The objective is to minimize or maximize some function of the arcs. Many LP type problems may be formulated as network models. IOPNET can handle large-scale problems easily since only a portion of the current basis is kept "in core" at any given pivot, while the complete network resides on disk. The package offers significant cost savings over standard LP codes due to its very fast primal simplex algorithm. IOPNET is easy to use since only two user files are required for execution. The command file defines the processing options and the data file contains the network model to be optimized.

Availability of Documentation

A reference manual is available from BCS to thoroughly describe the IOPNET package. Documentation and consultation services are supported by the ETA division in Seattle. The user may also obtain a copy of a sample of IOPNET using the data discussed on page 3 of the manual.

Input Requirements

IOPNET uses standard CDC FORTRAN IV file management protocol. User and program files are referred to as "TAPES" (e.g., TAPE5, TAPE6) and reside on card or disk devices, not actual magnetic tapes. The following two files are supplied by the user.

Program File	Default	Description
TAPE5	(INPUT)	This tape contains the commands necessary to instruct IOPNET what to do. The default action is to read from the standard input device, the terminal for timeshare users and the card reader for batch users.
TAPE13	(none)	The network data is also assumed to reside on the standard input device.

For these programmers familiar with CDC FORTRAN, the program header card is:

```
PROGRAM IOPNET(TAPE13,INPUT,OUTPUT,TAPE10,TAPE11,TAPE12,TAPE20,
   TAPE5=INPUT,TAPE6=OUTPUT)
```

Tapes 10, 11 and 12 are scratch files used during execution.

Output Options

Two files are available from IOPNET after processing is complete.

TAPE6	(OUTPUT)	This tape summarizes the results of the network flow problem and shows the optimal solution. The default action is to write on the standard output device, terminal for timeshare users and line printer for batch users.
TAPE20	(none)	The user may request the solution to be written to TAPE20 in a brief format for post-processing. Only the arcs with positive flow will be shown. No file will be written under the default action. If the user requests for the results in the command file, TAPE20 will be used.

Access Procedure

The process to execute IOPNET is simple. The user creates his two input files and then gets a copy of IOPNET from the system account, EKSAPP. For notation purposes, all files names in lower case are user supplied.

A standard batch run using all default options would consist of:

```
TEST,CM65000,T10,P06.
ACCOUNT,CWA,PASSOWRD.
GET,IOPNET/UN=EKSAPP.
IOPNET,INPUT.
REPLACE,TAPE20=answer.
 EOR
                (command file)
 /EOR
                (data file)
 /EOR
 ""             (end of job card)
```

IOPNET will read both input files from the card reader and list the results on the line printer. If the user requested for a solution file, TAPE20 would be created and renamed as "answer", then saved on the users account.

A standard terminal execution would be:

```
GET,IOPNET/UN=EKSAPP
GET,data,commands
IOPNET,data,commands,outfile
REPLACE,TAPE20=answer
REWIND,outfile

COPY,outfile

   or

DISPOSE,outfile=PR
```

The sequence of file names after IOPNET on line 3 is important and overrides the standard file defaults. The program output is written to "outfile" and is either written to the terminal by the COPY command or the line printer with the DISPOSE command.

Simple Example

The following run represents a complete job executed under the batch system. The user has his data file on disk (data) and wishes to obtain a listing of the data and two listings of the solution.

```
TEST,CM65000,T10,P06.
ACCOUNT,CWA,PASSWORD.
GET,IOPNET/UN=EKSAPP.
GET,data.
COPYSCR,data.
IOPNET,data,,outfile.
REWIND,outfile.
COPY,outfile.
REWIND,outfile.
COPY,outfile.
/EOR
REPORT 1
SOLVE  1      (command file)
QUIT
/EOR
 ''''
```

Note the use of the double comma on line 6. Since the call sequence on the execution card is usually in the order of data file, command file then output file, a space must be left to indicate the command file will reside on the standard input device, the card reader.

Access of a Sample Run

The example discussed above was actually run and the results are available for user demonstration. It shows the correct job setup for IOPNET plus the generated output. To obtain a copy in the timeshore mode;

```
GET,PNETDOC/UN=EKSAPP

COPY,PNETDOC

    or

DISPOSE,PNETDOC=PR
```

This will print on the terminal or line printer depending whether card 2 or 3 is used.

Extended Parameters

Since the access and execution procedure for IOPNET is so simple, there are few optional parameters. The reference manual discusses the basic options available in the command file.

Version and Field Length Specification

IOPNET is available in two forms to solve problems of different sizes. The user should attempt to use the smaller version if possible to reduce processing costs.

GET,IOPNET/UN=EKSAPP.   field length 65K

This version is capable of solving a problem with 500 nodes and 1933 capacitated arcs (arcs with upper and lower bounds). If the network is uncapacitated (no bounds), the arc limit increases to 2900.

GET,IOPNETL/UN=EKSAPP.   field length 200K

This enlarged version will handle problems up to 3000 nodes and 41000-62000 arcs.

APPENDIX F

OFFSHORE RECOVERY OF SAND AND GRAVEL: AN ALTERNATIVE TO INLAND MINING

Offshore Recovery Of Sand And Gravel: An Alternative To Inland Mining

by D.S. Cottell

The following is a paper presented at Oceanology International 1978 at Brighton, England, and published by the Institution of Mining and Metallurgy. The paper by D.S. Cotell, managing director of ARC Marine Limited, gives a short history and development of the Marine Aggregates Industry as it exists in the United Kingdom, together with a description of the licensing system, types of dredge employed, some detail on historic and current costs and speculation on the international opportunities and future. "Some International Opportunities for Marine Aggregates" explores the argument on the future opportunities.

Beginning with mainland Europe, already some three to four million tons per annum of marine aggregates are being shipped into mainland Europe by U. K. operators, the supplies coming in the main from U. K. licensed sources, as at present there appears to be only minimal interest being shown in developing the sea dredged aggregate industry either by local companies from their own indigenous resources. This is not to say that little work has been done.

In France, back in 1968 the National Center for the Exploration of the Ocean, together with the Bureau of Geological and Mining Research, undertook to compile an inventory of resources available on the Continental Shelf. At the same time, C. N. E. X. O. together with Scientific and Technical Institute of Fisheries are conducting studies on Repercussions of the Industrial Exploitation on the Marine Environment.

Their work to date indicates considerable deposits of aggregates existing on the French Continental Shelf of the English Channel and the Atlantic Ocean.

So we have a situation existing where there are proven deposits and little activity, so opportunity exists. Several credible observers have speculated that the Paris Region could be requiring marine aggregates to supplement depleting land reserves by 1980/82. They further speculate that by 1985, this region may be supplied by several million tons per annum.

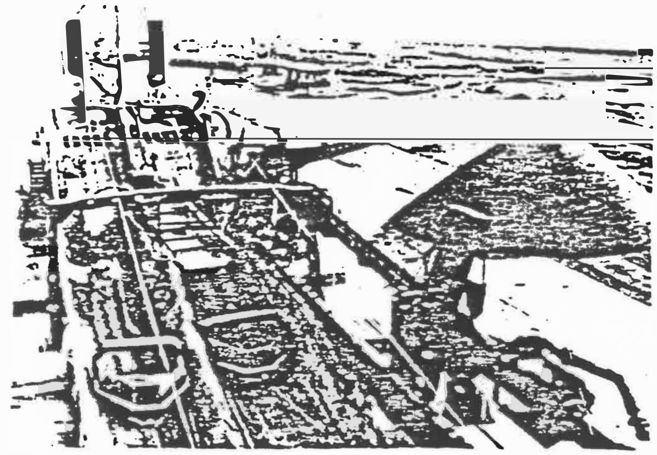
Brittany is another region where land reserves of sand are almost exhausted and marine sources are expected to amount to 2,000,000 tons per annum within the next five years.

Including the Paris Region with Northern France and Brittany, estimates ranging between 20-30 million tons per annum of sea-dredged aggregates production is postulated by 1985.

Holland has for many years been the world's leader in dredging techniques, construction of trailer dredges equipment and certainly has the world's largest dredging fleet. However, despite the industry's enormous size and worldwide reputation, surprisingly it has not exploited this expertise to any significant degree as regards dredging for marine aggregates. One of the reasons may be due to the fact that the more easily won resources are within the U. K. area of the Continental Shelf.

In recent years, more interest has been shown by both Dutch and Belgian operators and it must be expected this interest will continue. The greater proportion of aggregate used in the Netherlands comes from Rivers Maas and Rhine, yet most of the very important industrial and urban centers are considerable distances from the production centers, despite the fact that the greater majority of aggregates are transported by barges via the Canals and River systems at very economical rates.

It is expected that the future trend of increases in



The Arco Scheldt discharging sand and gravel at the new wharves at Shoreham.

freight costs will allow marine aggregates to compete with the land resources. So further opportunity exists.

Outside of Europe, opportunity exists for the future in developing a marine aggregates industry in both U. S. and the State of N. S. W. in Australia. In both these countries, abundant reserves have been located offshore within their jurisdiction.

Whilst there are adequate resources to ensure the supply viability of an industry, I believe the timing of such development and exploitation to be another question, and will be largely dictated by the speed of depletion of existing land resources, the product price in the market place, and environmental considerations.

If we consider the Eastern Sea Board of the U. S., various observers indicate reserves at between 2.5 and 4.5 billion tons in an area from New England to Virginia. In 1976, the Massachussetts Institute of Technology sea grant program produced an opportunity brief on Offshore Mining of Sand and Gravel. The business perspectives, rationale and conclusions are quoted as follows:

A Business Perspective

Sand and gravel are basic raw materials used in nearly all construction projects. Although available land-based reserves of sand and gravel are virtually inexhaustible on a global or national scale, regional shortages do exist and are rapidly becoming more severe and more widespread. Such regional shortages increase the delivered price of sand and gravel to the point that offshore recovery of these aggregates is becoming a financially attractive alternative to inland mining, particularly for coastal urban areas. Offshore mining of sand and gravel is already financially attractive and operational in the United Kingdom, Japan, and other countries.

The total market is very large — on the level of one to two billion dollars annually in the U. S. The fraction of the market that can profitably be obtained by sea-won resources is small today, but could grow rapidly within the next five to ten years.

Offshore recovery of sand and gravel will require large amounts of capital. The risks are also great and the uncertainties are abundant. In addition, environmental considerations presently raise severe regulatory and legal problems. However, comparable environmental problems are also associated with new landbased sources. There is evidence to suggest that offshore mining of sand and gravel may prove to be an attractive source of supply environmentally as well as economically.

No technological breakthroughs are needed to start an offshore sand and gravel mining industry, since requisite technology exists in dredging. However, detailed studies are required to ensure profitable operations at specific, selected locations because costs and prices are site-dependant, varying strongly with local geological and market factors.

The initiation of offshore sand and gravel mining would present a broad range of new business opportunities for U. S. industries. Clearly, the greatest opportunities would exist for manufacturers of dredging equipment and mining systems, offshore mining companies, and vendors of construction aggregates. In addition, new opportunities could be expected to develop for companies providing related services and products.

The Rationale for Offshore Mining of Sand and Gravel

• *The growing demand for construction aggregates.*

In almost any sizeable construction project, such as highways, buildings, or bridges, a principal material required is sand, gravel or crushed stone. Supplying these construction mineral aggregates is a multibillion dollar industry. In 1972, construction projects in the U. S. consumed some 1.6 billion tons of aggregates at a value of $2.3 billion divided almost equally between sand and gravel and crushed stone.

Although 1974 production was lower, amounting to about 900 million tons valued at $1.6 billion, forecasts by the U. S. Bureau of Mines indicate that the demand for construction aggregates will continue to rise slowly at about four per cent annually throughout the century. Although the historical data do not seem to justify such a high rate, it would nevertheless appear that the consumption of sand and gravel aggregates will at least double and may triple by the year 2000.

• *The restricted supply of land-based aggregates.*

As cities and surburbs expand, existing supplies of sand and gravel are depleted and potential supplies become inaccessible beneath highways, buildings, factories, and homes. Thus, mining operations are gradually being forced further from the market areas in which the demand is greatest, increasing the delivered cost of sand and gravel.

Because of the high bulk and low value of construction aggregates, transportation costs are a major element in determining the delivered price of sand and gravel. The industry is highly concentrated near urban centers. A study by Bronitsky has shown that all of the construction aggregates used in the New York Metropolitan area come from within a 60 mile radius of the city. Thus, an extensive sand and gravel deposit in the Rocky Mountains is, for all practical purposes, inaccessible to New York City's construction industry.

Since new sources of land-based sand and gravel may not always meet the user's specifications, additional processing may be required, increasing the cost and creating environmental problems.

Increasingly strict environmental controls on land-based mining operations, coupled with increased prices, further suggest that the availability of reasonably priced construction aggregates near urban areas will continue to decrease.

Virtually all construction aggregates now used in the U. S. are mined from land-based sources, which will doubtless continue to supply the construction requirements of the interior areas of the U. S. However, for coastal urban areas, offshore sand and gravel could supplement, and perhaps eventually replace, land-based sources.

• *The abundance of offshore sand and gravel.*

Marine deposits of sand and gravel are very large indeed. The upper ten feet of the ocean floor off the northeastern part of the U. S. has been estimated to contain about 450 billion tons of sand — a sufficient supply to meet construction needs for hundreds of years. Specific studies of local deposits of offshore aggregates have been done off the southeastern states, northeastern states, California, Hawaii, the New York Bight, and in Long Island Sound. All these studies revealed vast amounts of exploitable mineral aggregates that could be made available to coastal metropolitan centers where a very substantial amount of U. S. construction occurs.

These studies are far from complete from the viewpoint of commercial mining of sand and gravel, but they do suggest that we can look to the coastal offshore areas as a source of supply.

For the marine mining of sand and gravel, just as for land mining, the economics of distribution and transportation are of key importance. Sand and gravel, after being recovered on the open sea, must be transported to a marine terminal, unloaded, processed (washed in some cases), stored, and then reloaded on trucks for shipment to a construction site. Thus, marine based sand and gravel has a geographically limited market — one that can be defined as a few tens of miles from the seacoast.

Summary and Conclusions

1. Offshore mining of sand and gravel could become a viable business in the U. S. Current trends in delivered prices for land-based sources, growing environmental problems for land-based sources, adequacy and proximity of reserves offshore, and depletion of reserves on land — all point towards the future use of the offshore resource.

2. Impediments to the development and growth of an offshore sand and gravel industry are:

a. The legal and environmental uncertainties associated with offshore mining, which will increase the financial risk of the offshore miner.

b. A lack of offshore dredges in the U. S., which will require large capital outlays to develop an efficient fleet. The large capital requirement and the risks associated with (a) above prohibit rapid development of the new industry.

c. Detailed geological studies are needed to locate the most desirable sources of offshore supply for each market area.

3. While the considerations in 2 a, b, and c above, may temporarily impede U. S. mining of offshore sand and gravel and make estimation of a developmental time frame difficult, they simultaneously represent a source of new business opportunities for companies with capabilities to assist in overcoming the impediments.

4. The foreign dredging technology seems adequate

and appropriate for use in the U. S., but the legal requirements for U. S. construction of dredges will mean very much higher costs than in the U. K.

Turning from U. S. to Australia, in March 1977, a report was published by the N. S. W. Government on the findings of the environmental investigations into the extractive industries in the Sydney Basin area. This report estimated that this Region would consume 700 million tons of sand and gravel between 1976 and the year 2000, and that possibly 100 million tons would have to be imported from long distances to meet demand. Some observers have speculated that up to 20 per cent of this demand could be met from marine resources by the Mid 1980's.

As an example, this region has an estimated requirement of 400 million tons of sand during this period 1976-2000. There are total known reserves in the area of 275 million tons of which it is expected only 125 million tons are secured. Dr. Ian Wallace of the N. S. W. Geological Survey Branch commented on the future rule of marine aggregates in a paper presented to the Institute of Quarrying as follows: "The topic of marine aggregates has been left to last owing to its somewhat uncertain future.

It is known there are significant deposits of sand and gravel off the N. S. W. coastline though in many areas there is an absence of gravel, and in other areas the gravel deposits are overlain by sand and other sediments. The extraction of these deposits raise many complex issues which will not be discussed here. The major question at present influencing the future development of marine aggregates is, whether the offshore deposits come under the State or Commonwealth jurisdiction. If marine aggregates sources are developed in the future, the overall demand/supply situation particularly with regard to sand will be significantly improved".

Since Dr. Wallace presented this paper in 1974, a significant advance has been made regarding the jurisdiction.

At a Prime Minister's conference involving States and Commonwealth Government last October, agreement was reached whereby the States were granted Administration Authority over their offshore resources. Whilst final Commonwealth Legislation is not expected for at least a year, several States have invited applications for exploration licenses for minerals offshore, and it is intended that such licenses will be issued under the States existing Mining Acts.

This is a big leap forward, as this question of jurisdiction has been an issue between States/Commonwealth Government for over seven years, and it does bring nearer the development and opportunity in this region.

These specific opportunities and other worldwide possibilities lead me to the conclusion, that there is a significant future for both operator and manufacturer in this industry.■

APPENDIX G

RECORD SAND AND GRAVEL VOLUME DELIVERED TO RIVER THAMES

Record Sand And Gravel Volume Delivered To River Thames

A record one million tons of dredged sand and gravel was delivered to the River Thames terminal of Brett Marine Aggregates Ltd. near Rochester, Kent, during 1980 — establishing it as Europe's largest depot for marine dredged aggregate. The material was won and delivered by the self-discharging gravel trailer Marinestone (2,206 gross tons) operated by Westminster Gravels Ltd., a Southampton based subsidiary of Royal Boskalis Westminster.

Despite further economic recession this year, Westminster Gravels is continuing to supply Bretts with aggregate on a satisfactory level, and there are strong grounds for optimism.

The success of this operation — one of many long term supply contracts which Westminster Gravels is currently engaged in — is due to several factors, such as the quality of the aggregate, flexibility and reliability of service and the excellent relationship which client and supplier enjoy.

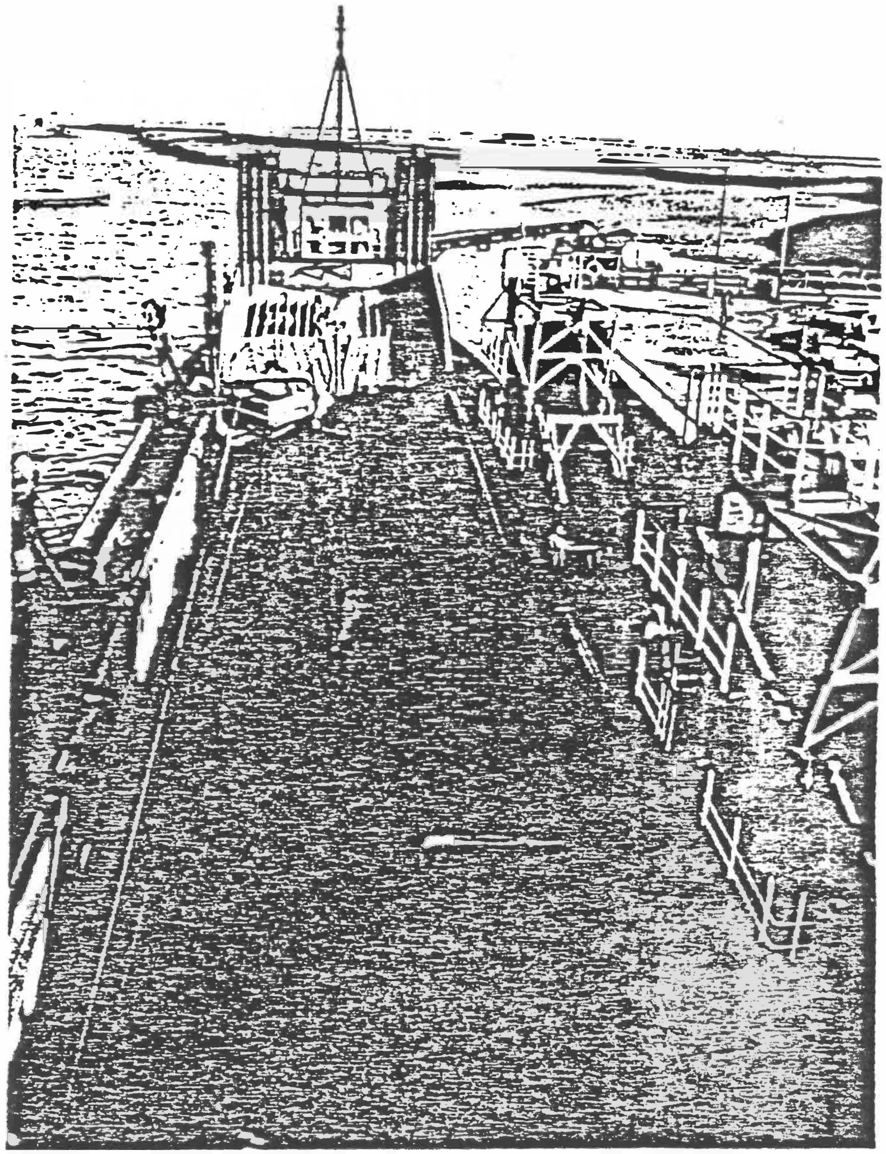
John Douglas, general manager and director of Brett Marine Aggregates Ltd. said, "The demand for different grades of aggregate can change quite easily, therefore it is essential to maintain flexibility of supply. Our supplier has got a variety of winning areas to choose from, which is very good from our point of view."

Brett Marine Aggregates was formed in 1976 following the takeover of Marinex Gravel Ltd.. by its parent company, the Robert Brett Group.

Marinex Gravel Ltd. owned the gravel trailer which Westminster Gravels Ltd. now operates in and out of the Cliffe aggregate terminal — the Marinestone.

Built in 1972 and measuring in length 84m overall, the Marinestone was designed specifically for winning marine aggregates. With bridge situated forward and the self-discharging gear located in the aft position.

The Marinestone on-board screening system consists of two towers situated on the starboard side of the vessel, one of which screens the aggregate and discharges into the hopper and the other discharges the unwanted spoil over the side. Both towers can revolve, a feature which enables the Marinestone's 3,000 tons capacity hopper to be filled evenly from the on-board discharging facility.



The Marinestone unloading at Brett's River Thames terminal, with assistance from the vessel's two giant hopper buckets each having a capacity of 12.5 tons.

A special feature of the Marinestone's performance is the speed with which the discharging operation begins. Within minutes of the vessel arriving at the Cliffe jetty the on-board conveyor is swung out and the two giant hopper buckets (12.5 tons capacity each) begin to scoop up the dredged aggregate and so set the process in motion. Operating at a rate of 1,000 tons per hour, the Marinestone can deposit its load in three hours. As soon as the discharging is completed the Marinestone turns about and heads back to the winning area, which could be up to 100 miles away, to collect another load. This cycle continues 24 hours per day, seven days per week, continuously throughout the year.

The speed of the whole operation is enhanced considerably by the fact that the jetty has sufficient depth of water to enable the

Marinestone to berth and discharge at any time during the day or night. Being a self-discharging ship, there are no delays associated with shore-based handling procedures either.

According to Mick Mason, the commercial director for Westminster Gravels, the aggregate dredged by Marinestone is good quality material and therefore suitable for ready mixed concrete production after processing. Brett Marine Aggregates regularly supplies up to 15 concrete plants in the south east of England. A good quality aggregate, explained Mason, will be clean and have a rounded shape, rather than a thin elongated one. Size is obviously important too as is the sand to gravel ratio. A cargo will, ideally, contain two-thirds gravel and one-third sand.

The type of material required by the client determines which of the winning areas the Marinestone goes to. Different locations provide different grades of material. However, it is important to know where within the winning areas the good supplies of aggregate can be found. The quicker the Marinestone can fill its hopper with the required grade of material, the more economical the operation becomes. This has obvious advantages for the supplier and in the long run for the client.

Deciding where to dredge is the responsibility of the ship's master in conjunction with the company's operations department in Southampton.

Situated at Cliffe and covering an area of 13.5 acres, the processing plant of Brett Marine Aggregates is designed to operate at the rate of 400 tons per hour. In practice, however, a rate of 300 tons per hour is aimed for in order to meet the increasingly strict specifications laid down by the company's clients.

During processing of the marine aggregate the sand is separated and fed to three cones and three dewatering screens before stockpiling, whilst the gravel is graded and screened into three main sizes and either stored in bunkers or open stockpiled by means of finger conveyors. The terminal is linked by road and also connected by an efficient rail network, an unusual but effective feature within the aggregate industry.

With this dual transport facility, distribution throughout the south east of England, including London, can be achieved quickly and efficiently. The company boasts that a batch of gravel can be discharged, processed, dispatched and actually be mixed into concrete up to 50 miles away — all within 24 hours.

Some two thirds of the Kent terminal's total output is dispatched by rail. There are 24 train movements each week. The first train in the morning departs at 3.05 hours and the last train at night leaves at 20.05 hours. Each train consists of nine, 72 ton wagons designed for bottom discharging. Loading is by means of an overhead tripper loader, operating at 6.5 tons per minute, which feeds one of two 240 foot sidings.

In total there are about 12,000 feet of conveyors operational at the processing plant and some 400,000,000 gallons of fresh water are used annually. Buildings on the site include a sub-station, pump house, weighbridge, offices and a control room which houses a data processing system for controlling the loading of both road and rail vehicles.

Conveying the dredged aggregate from the jetty stockpile to the plant, which is situated a considerable distance away, involves the use of three, 30 inch conveyors which have a combined length of over one mile. Fed by tractor shovel and running at ground level parallel to the jetty approach road, the conveyor rises to a height of 50 feet for discharge into a transfer chute. The screening, washing and grading processes then follow before the sand and gravel are stockpiled.■

APPENDIX H

COMPUTER PROGRAM

INTRODUCTION TO COMPUTER PROGRAM

The computer program contained on the following pages has been designed to be run on a hand-held Hewlett-Packard (HP) - 41C/CV.

Implementing the program, as designed, the user can update and revise the quantities of sand and gravel used for land development. The quality of the computer results are directly related to the data obtained from owners and contractors for various types of developments.

Table A-1.11, Appendix I, delineates in terms of footnotes, the applicable equations to the balance of the Private Development tables.

The computer program is intended to be utilized to continually update and monitor sand and gravel consumption throughout the range of zoned properties within the Municipality of Anchorage.

HP 412/CV PROGRAM FOR TABLE A1.1 TO A1.12

ANCHORAGE NATURAL RESOURCES EXTRACTION STUDY

PRP "MES"

```
01    LBL "MES"
02    LBL 01
03    "L AREA?"          LAND AREA IN ACRES
04    PROMPT
05    STO 21
06    43560
07    *
08    STO 20
09    "RAM?"             ROAD AREA MULTIPLIER (% LAND COVER OF TOTAL AREA)
10    PROMPT
11    RCL 20
12    X<>Y
13    %
14    STO 27
15    "BASE?"            STREET BASE IN FEET
16    PROMPT
17    *
18    STO 24
19    27
20    ÷
21    STO 31
22    STOP.
23    "%PARK, DR ?"      % PARKING/DRIVEWAY AREA OF TOTAL AREA
24    PROMPT
25    RCL 20
26    X<>Y
27    %
28    STO 28
29    "BASE?"            PARKING/DRIVE PAVEMENT BASE THICKNESS
30    PROMPT
31    *
32    STO 26
33    27
34    ÷
```

35	ST + 32	
36	ST + 31	
37	STOP	
38	"UM ?"	UTILITY MULTIPLIER (EXPRESSED AS A DECIMAL FRACTION OF ROAD VOLUME)
39	PROMPT	
40	RCL 24	
41	*	
42	27	
43	÷	
44	ST + 33	
45	STOP	
46	ST + 31	
47	"CONC USE ?"	CONCRETE USE IN CF/ACRE (SEE TABLE A1.12)
48	PROMPT	
49	RCL 21	
50	*	
51	27	
52	÷	
53	ST + 34	
54	STOP	
55	ST + 31	
56	RCL 27	
57	RCL 28	
58	+	
59	.3	
60	*	
61	27	
62	÷	
63	ST + 35	
64	STOP	
65	ST + 31	
66	"BACKFILL ?"	UNIT VOLUME OF GRAVEL BACKFILL (SEE TABLE A1.13)
67	PROMPT	
68	RCL 21	
69	*	
70	27	
71	÷	
72	ST + 36	
73	STOP	

```
74    ST + 31
75    RCL 31
76    STOP        TOTAL CUBIC YARDS OF GRAVEL FOR GROSS ACREAGE
77    RCL 21
78    ÷
79    STOP        TOTAL CUBIC YARDS GRAVEL/ACRE DEVELOPED
80    GTO 01
81    END
```

STORAGE ALLOCATION	REGISTER #
LAND AREA, SF	20
LAND AREA, ACRES	21
VOLUME GRAVEL, ROADS, CF	24
VOLUME GRAVEL, REQUIRED (RUNNING ACCUMULATION)	31

APPENDIX I

ESTIMATED SAND AND GRAVEL USE, PRIVATE DEVELOPMENT

TABLE A-1.1 - Anchorage Estimated Sand and Gravel Use, Private Development

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	9	10	11	12	13	14
ZONING SHEET[1]	LAND AREA,AC	ZONING	STREETS M[2]	D[3]	VOLUME[4]	PARKING/DRIVEWAYS M[5]	D[3]	VOLUME	UTILITIES M[6]	VOLUME	CONCRETE[7] VOLUME	ASPHALT/ BASE[8]	BUILDING BACKFILL[9]
19-1	57.38	R-1	28	2.4	62,206	20	1.5	13,885	.8	49,765	3,040	10,553	26,661
19-2	54.84	R-1	28	2.4	59,456	10	1.5	13,272	.8	47,565	2,904	10,086	25,483
18-1	18.79	R-6	12	2.4	8,730	0	--	--	0	--	237	--	1,820
18-2	24.70	R-6	12	2.4	11,475	0	--	--	0	--	312	--	2,392
18-3	77-90	R-6	12	2.4	36,194	0	--	--	0	--	984	--	7,544
27-1	319.39	R-1A	28	2.4	346,267	10	1.5	77,292	.8	277,013	12,752	58,742	133,551
25-1	50.76	R-7	20	1.2	19,656	15	1.5	18,427	0	--	1,282	8,599	10,484
25-2	80.00	R-6	12	1.5	23,232	0	--	--	0	--	1,010	--	7,748
25-3	116.23	U	12	2.4	54,004	0	--	--	0	--	1,468	--	11,257
12-1	45.67	B-3	20	2.4	35,368	64	1.5	70,737	.8	28,295	7,840	18,568	84,916
12-2	8.18	R-1	28	2.4	8,870	10	1.5	1,980	.8	7,096	433	1,505	3,802
12-3	14.59	R-2A	24	2.4	13,556	15	1.5	5,295	.8	10,845	541	2,754	10,374
12-4	26.55	R-3	24	2.4	24,669	30	1.5	19,272	.8	19,735	4,797	5,653	5,211
12-5	15.76	R-2	24	2.4	14,643	15	1.5	5,720	.8	11,715	578	2,974	11,593
12-6	83.29	R-2	24	2.4	77,395	15	1.5	30,232	.8	61,916	3,054	15,721	61,273
PAGE TOTALS:					795,721			256,112		513,945	41,232	135,155	404,109

TABLE A-1.2 - Anchorage Estimated Sand and Gravel Use, Private Development

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ZONING SHEET[1]	LAND AREA,AC	ZONING	STREETS M[2]	D[3]	VOLUME[4]	PARKING/DRIVEWAYS M[5]	D[3]	VOLUME	UTILITIES M[6]	VOLUME	CONCRETE[7] VOLUME	ASPHALT/ BASE[8]	BUILDING BACKFILL[9]
22-1	60.24	R-6	12	1.2	13,994	0	--	--	0	--	761	--	5,834
22-2	13.66	R-6	12	1.2	3,174	0	--	--	0	--	173	--	1,323
22-3	172.36	R-6	12	1.2	40,042	0	--	--	0	--	2,176	--	16,693
22-4	24.98	R-6	12	1.2	5,803	0	--	--	0	--	316	--	2,419
22-5	78.02	R-6	12	1.2	18,125	0	--	--	0	--	985	--	7,556
22-6	56.71	R-6	12	1.2	13,175	0	--	--	0	--	716	--	5,493
22-7	45.27	R-6	12	1.2	10,517	0	--	--	0	--	572	--	4,384
21-1	53-17	R-3	24	2.4	49,414	30	1.5	38,605	.8	39,532	9,609	11,324	104,380
21-2	32.72	B-3	20	2.4	25,338	64	1.5	50,678	.8	20,270	5,617	13,302	60,834
21-3	43.41	R-2A	24	2.4	40,431	15	1.5	15,758	.8	32,273	1,609	8,194	30,870
21-4	20.40	R-3SL	24	2.4	18,955	30	1.5	14,808	.8	15,164	3,686	4,344	40,039
21-5	21.73	R-1SL	28	2.4	23,561	10	1.5	5,259	.8	18,849	1,151	3,997	10,098
21-6	32.56	R-3SL	24	2.4	30,256	30	1.5	23,637	.8	24,205	5,883	6,934	63,911
21-7	34.47	R-3SL	24	2.4	32,032	30	1.5	25,025	.8	25,626	6,229	7,341	67,663
21-8	48.11	R-1A	28	2.4	52,160	10	1.5	11,643	.8	41,728	1,921	8,848	20,117
21-9	29.36	R-1SL	28	2.4	31,830	10	1.5	7,105	.8	25,464	1,555	5,400	13,642
21-10	39.93	R-6	12	1.5	11,597	0	--	--	0	--	504	--	3,868
21-11	58.03	R-1	28	2.4	62,919	10	1.5	14,044	.8	50,335	3,074	10,674	26,967
21-12	78.79	R-1A	28	2.4	85,419	10	1.5	19,067	.8	68,335	3,146	14,491	32,945
21-13	108.90	R-1	28	2.4	118,065	10	1.5	26,354	.8	94,452	5,768	20,029	50,602
21-14	37.29	R-6	12	1.5	10,829	0	--	--	0	--	471	--	3,611
PAGE TOTALS:					697,636			251,983		456,233	55,922	114,878	573,249

TABLE A-I.3 - Anchorage Estimated Sand and Gravel Use, Private Development

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ZONING SHEET[1]	LAND AREA,AC	ZONING	STREETS M[2]	D[3]	VOLUME[4]	PARKING/DRIVEWAYS M[5]	D[3]	VOLUME	UTILITIES M[6]	VOLUME	CONCRETE[7] VOLUME	ASPHALT/ BASE[8]	BUILDING BACKFILL[9]
25-4	140.00	R-6	12	1.5	40,656	0	--	--	0	--	1,768	--	13,559
24-1	198.67	R-6	12	1.5	57,695	0	--	--	0	--	2,509	--	19,242
20-1	53.94	I-1	20	2.7	46,992	30	2.0	52,213	.8	37,594	10,229	13,053	111,395
20-2	70.97	I-2	20	2.7	61,832	30	2.0	68,702	.8	49,466	13,459	17,176	146,573
20-3	9.48	R-1A	28	2.4	10,283	10	1.5	2,295	.8	8,226	379	1,744	3,966
20-4	13.52	R-2A	24	2.4	12,565	15	1.5	4,908	.8	10,052	501	2,552	9,615
20-5	15.42	R-2SL	24	2.4	14,329	15	1.5	5,597	.8	11,463	565	2,910	11,344
20-6	169.08	R-1	28	2.4	183,312	10	1.5	40,918	.8	146,650	8,955	31,098	78,567
20-7	142.42	R-1	28	2.4	154,411	10	1.5	34,467	.8	123,529	7,543	26,195	66,180
7-1	94.83	D-3	24	2.4	88,128	20	1.5	45,900	.8	70,502	17,137	20,196	186,157
7-2	10.77	D-3	24	2.4	10,005	20	1.5	5,211	.8	8,004	1,946	2,293	21,135
7-3	25.09	R-3	24	2.4	23,320	30	1.5	18,219	.8	18,656	4,535	5,344	49,260
7-4	17.97	D-2	24	2.4	16,700	15	1.5	6,523	.8	13,360	626	3,392	13,221
7-5	16.43	B-3SL	20	2.4	12,727	64	1.5	25,454	.8	10,182	2,821	6,682	30,557
7-6	50.51	R-3	24	2.4	46,933	30	1.5	36,666	.8	37,547	9,126	10,756	99,140
7-7	28.07	R-4	24	2.4	26,082	20	1.5	13,584	.8	20,866	6,266	5,977	68,829
7-8	8.06	D-2	24	2.4	7,488	15	1.5	2,925	.8	5,990	295	1,521	5,928
7-9	10.00	D-2	24	2.4	9,293	15	1.5	3,630	.8	7,434	367	1,888	7,357
7-10	9.10	D-2	24	2.4	8,459	15	1.5	3,304	.8	6,767	334	1,718	6,697
PAGE TOTALS:					831,210			370,516		586,288	89,361	154,495	948,722

TABLE A-1.4 - Anchorage Estimated Sand and Gravel Use, Private Development

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ZONING SHEET[1]	LAND AREA,AC	ZONING	STREETS M[2]	D[3]	VOLUME[4]	PARKING/DRIVEWAYS M[5]	D[3]	VOLUME	UTILITIES M[6]	VOLUME	CONCRETE[7] VOLUME	ASPHALT/ BASE[8]	BUILDING BACKFILL[9]
8-1	8.25	R-2	24	2.4	7,667	15	2.5	2,995	.8	6,133	303	1,557	6,070
8-2	8.25	R-3	24	2.4	7,667	30	1.5	5,989	.8	6,133	1,491	1,757	16,195
8-3	5.52	R-4	24	2.4	5,126	20	1.5	2,670	.8	4,101	1,232	1,175	13,528
8-4	54.73	R-3	24	2.4	50,861	30	1.5	39,735	.8	40,689	9,890	11,656	107,436
8-5	38.74	R-2	24	2.4	36,000	15	1.5	14,063	.8	28,800	1,420	7,313	28,501
8-6	15.99	R-2A	24	2.4	14,861	15	1.5	5,805	.8	11,889	593	3,019	11,372
8-7	37.28	R-1	28	2.4	40,422	10	1.5	9,023	.8	32,338	1,975	6,854	17,325
8-8	33.57	I-1	20	2.4	26,000	30	1.5	24,375	.8	20,800	6,367	8,125	69,337
8-9	19.11	B-3SL	20	2.4	14,800	64	1.5	29,600	.8	11,840	3,281	7,770	35,533
8-10	16.01	R-2	24	2.4	14,880	15	1.5	5,813	.8	11,904	587	3,023	11,780
8-11	4.13	R-2	24	2.4	3,840	15	1.5	1,500	.8	3,072	152	780	3,040
8-12	4.13	R-2	24	2.4	3,840	15	1.5	1,500	.8	3,072	152	780	3,040
8-13	6.20	R-2	24	2.4	5,760	15	1.5	2,250	.8	4,608	227	1,170	4,560
8-14	2.07	R-2	24	2.4	1,920	15	1.5	750	.8	1,536	76	390	1,520
8-15	6.20	R-2	24	2.4	5,760	15	1.5	2,250	.8	4,608	227	1,170	4,560
8-16	6.20	R-3	24	2.4	5,760	30	1.5	4,500	.8	4,608	1,120	1,320	12,167
8-17	2.07	B-3	20	2.4	1,600	64	1.5	3,200	.8	1,280	355	840	3,841
8-18	2.07	R-2	24	2.4	1,920	15	1.5	750	.8	1,536	76	390	1,520
8-19	2.07	R-3	24	2.4	1,920	30	1.5	1,500	.8	1,536	373	440	4,056
8-20	2.07	R-3	24	2.4	1,920	30	1.5	1,500	.8	1,536	373	440	4,056
8-21	4.13	R-3	24	2.4	3,840	30	1.5	3,000	.8	3,072	747	880	8,111
8-22	6.20	R-3	24	2.4	5,760	30	1.5	4,500	.8	4,608	1,120	1,320	12,167
PAGE TOTALS:					262,124			167,268		209,699	32,137	62,169	379,715

TABLE A-1.5 - Anchorage Estimated Sand and Gravel Use, Private Development

(1) ZONING SHEET[1]	(2) LAND AREA, AC	(3) ZONING	(4) STREETS M[2]	(5) D[3]	(6) VOLUME[4]	(7) PARKING/DRIVEWAYS M[5]	(8) D[3]	(9) VOLUME	10 UTILITIES M[6]	(11) VOLUME	(12) CONCRETE[7] VOLUME	(13) ASPHALT/ BASE[8]	14 BUILDING BACKFILL[9]
10-1	5.26	R-2A	24	2.4	4,886	15	1.5	1,909	.8	3,909	195	993	3,739
10-2	81.82	R-2A	24	2.4	76,030	15	1.5	29,699	.8	60,824	3,033	15,444	58,180
10-3	10.00	R-2A	24	2.4	9,293	15	1.5	3,630	.8	7,434	371	1,888	7,111
10-4	10.00	R-2A	24	2.4	9,293	15	1.5	3,630	.8	7,434	371	1,888	7,111
10-5	10.00	R-3	24	2.4	9,293	30	1.5	7,260	.8	7,434	1,807	2,130	19,630
11-1	109.33	I-1	20	2.4	84,661	30	1.5	79,370	.8	67,729	20,731	26,457	225,776
11-2	64.24	I-1	20	2.4	49,745	30	1.5	46,636	.8	39,796	12,181	15,545	132,660
11-3	40.71	I-1	20	2.4	31,529	30	1.5	29,558	.8	25,223	7,721	9,853	84,082
11-4	6.02	I-1	20	2.4	4,663	30	1.5	4,372	.8	3,730	1,142	1,457	12,436
11-5	39.74	R-3	24	2.4	36,926	30	1.5	28,848	.8	29,541	7,180	8,462	78,000
11-6	23.47	I-1	20	2.4	18,176	30	1.5	17,040	.8	14,540	4,451	5,680	48,472
11-7	74.02	R-3	24	2.4	68,783	30	1.5	53,736	.8	55,026	13,375	15,763	145,294
11-8	49.36	B-3	20	2.4	38,208	64	1.5	76,416	.8	30,566	8,470	20,059	91,734
11-9	33.15	I-1	20	2.4	25,668	30	1.5	24,063	.8	20,534	6,285	8,021	68,451
PAGE TOTAL:					467,154			406,197		373,720	87,313	133,640	982,676

TABLE A-1.6 - Anchorage Estimated Sand and Gravel Use, Private Development

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ZONING SHEET[1]	LAND AREA,AC	ZONING	STREETS M[2]	D[3]	VOLUME[4]	PARKING/DRIVEWAYS M[5]	D[3]	VOLUME	UTILITIES M[6]	VOLUME	CONCRETE[7] VOLUME	ASPHALT/ BASE[8]	BUILDING BACKFILL[9]
13-1	15.17	R-2A	24	2.4	14,096	15	1.5	5,506	.8	11,277	562	2,863	10,786
13-2	8.29	R-3	24	2.4	7,701	30	1.5	6,016	.8	6,160	1,497	1,765	16,266
13-3	22.67	R-2A	24	2.4	2,164	15	1.5	8,228	.8	16,851	840	4,279	16,119
13-4	22.67	B-1	20	2.4	17,554	60	1.5	32,913	.2	3,511	3,891	8,777	42,144
13-5	7.31	R-1	28	2.4	7,930	10	1.5	1,770	.8	6,344	387	1,345	3,399
13-6	11.02	B-4	12	2.4	5,120	40	1.5	10,667	0	--	1,892	2,773	20,488
13-7	60.61	R-2A	24	2.4	56,320	15	1.5	22,000	.8	45,056	2,247	11,440	43,098
13-8	36.77	R-1A	28	2.4	39,870	10	1.5	8,899	.8	31,896	1,468	6,764	15,377
13-9	11.36	R-2	24	2.4	10,560	15	1.5	4,125	.8	8,448	417	2,145	8,360
13-10	55.45	R-2A	24	2.4	51,532	15	1.5	20,130	.8	41,225	2,056	10,467	39,434
13-11	11.69	B-3SL	20	2.4	9,053	64	1.5	18,107	.8	7,243	2,007	4,753	21,736
13-12	7.13	R-2A	24	2.4	6,630	15	1.5	2,590	.8	5,304	265	1,347	5,074
13-13	117.65	R-2A	24	2.4	109,326	15	1.5	42,705	.8	87,460	4,362	22,207	83,659
13-14	18.79	R-2	24	2.4	17,459	15	1.5	6,820	.8	13,967	689	3,546	13,822
13-15	56.49	R-2	24	2.4	52,493	15	1.5	20,505	.8	41,994	2,071	10,663	41,558
13-16	4,21	R-2	24	2.4	3,910	15	1.5	1,528	.8	3,128	154	794	3,096
13-17	4.60	R-3	24	2.4	4,275	30	1.5	3,341	.8	3,420	831	980	9,031
13-18	16.02	B-3	20	2.4	12,409	64	1.5	24,818	.8	9,927	2,751	6,515	29,793
13-19	8.18	R-2	24	2.4	7,598	15	1.5	2,968	.8	6,078	300	1,543	6,015
PAGE TOTAL:					436,000			243,636		349,289	28,687	104,966	429,255

TABLE A-1.7 - Anchorage Estimated Sand and Gravel Use, Private Development

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	9	10	11	12	13	(14)
ZONING SHEET[1]	LAND AREA,AC	ZONING	STREETS M[2]	D[3]	VOLUME[4]	PARKING/DRIVEWAYS M[5]	D[3]	VOLUME	UTILITIES M[6]	VOLUME	CONCRETE[7] VOLUME	ASPHALT/ BASE[8]	BUILDING BACKFILL[9]
15-1	26.14	R-2	24	2.4	24,294	15	1.5	9,490	.8	19,436	959	4,935	19,234
15-2	9.62	R-1	28	2.4	10,431	10	1.5	2,328	.8	8,345	510	1,769	4,471
15-2	44.26	R-1	28	2.4	47,981	10	1.5	10,710	.8	38,385	2,344	8,140	20,564
15-4	13.06	R-2	24	2.4	12,134	15	1.5	4,740	.8	9,708	479	2,465	9,607
15-5	8.84	R-1	28	2.4	9,586	10	1.5	2,140	.8	7,669	468	1,626	4,109
15-6	19.72	R-1	28	2.4	21,378	10	1.5	4,772	.8	17,103	1,044	3,627	9,163
16-1	36.26	R-2	24	2.4	33,693	15	1.5	13,161	.8	26,955	1,329	6,844	26,675
16-2	80.61	R-2	24	2.4	74,907	15	1.5	29,260	.8	59,925	2,956	15,215	59,303
16-3	58.05	R-1	28	2.4	62,937	10	1.5	14,048	.8	50,349	3,075	10,677	26,974
16-4	29.30	R-2	24	2.4	27,227	15	1.5	10,635	.8	21,781	1,074	5,530	21,555
16-5	219.07	R-1	28	2.4	237,502	10	1.5	53,014	.8	190,002	11,602	40,291	101,793
16-6	168.35	I-2	20	2.4	130,373	30	1.5	122,225	.8	104,299	31,925	40,742	347,682
16-7	24.90	I-1	20	2.4	19,286	30	1.5	18,081	.8	15,429	4,723	6,027	51,433
16-8	34.50	I-2	20	2.4	26,716	30	1.5	25,046	.8	21,372	6,542	8,349	71,246
16-9	50.41	I-1	20	2.4	39,040	30	1.5	36,600	.8	31,232	9,560	12,200	104,113
16-10	80.56	I-2	20	2.4	62,389	30	1.5	58,490	.8	49,911	15,277	19,497	166,381
PAGE TOTAL:					839,874			414,740		671,901	93,867	187,934	1,044,303

TABLE A-1.8 - Anchorage Estimated Sand and Gravel Use, Private Development

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ZONING SHEET[1]	LAND AREA,AC	ZONING	STREETS M[2]	D[3]	VOLUME[4]	PARKING/DRIVEWAYS M[5]	D[3]	VOLUME	UTILITIES M[6]	VOLUME	CONCRETE[7] VOLUME	ASPHALT/ BASE[8]	BUILDING BACKFILL[9]
17-1	140.00	B-3	20	2.4	108,416	64	1.5	216,832	.8	86,733	24,033	56,918	260,296
17-2	21.21	R-2	24	2.4	19,712	15	1.5	7,700	.8	15,770	778	4,004	15,606
17-3	80.53	R-2A	24	2.4	74,837	15	1.5	29,233	.8	59,870	2,986	15,201	57,268
17-4	26.75	I-1SL	20	2.4	20,713	30	1.5	19,418	.8	16,570	5,072	6,473	55,238
17-5	37.15	B-3SL	20	2.4	28,770	64	1.5	57,540	.8	23,016	6,378	15,104	69,074
17-6	1.19	I-1	20	2.4	924	30	1.5	867	.8	740	226	289	2,465
17-7	79.43	R-3SL	24	2.4	73,813	30	1.5	86,501	.8	59,051	14,353	20,760	145,919
17-8	14.33	R-1SL	28	2.4	15,531	10	1.5	3,467	.8	12,425	759	2,635	6,656
17-9	5.46	R-3	24	2.4	5,077	30	1.5	3,966	.8	4,062	987	1,164	10,725
17-10	97.44	I-2	20	2.4	75,461	30	1.5	70,745	.8	60,369	18,478	23,582	201,242
17-11	69.08	I-1	20	2.4	53,493	30	1.5	50,150	.8	42,795	13,099	16,717	142,657
17-12	3.73	B-1	20	2.4	2,889	60	1.5	5,417	.2	578	640	1,444	6,936
17-13	25.67	R-3	24	2.4	23,853	30	1.5	18,636	.8	19,083	4,638	5,466	50,386
17-14	56.25	R-1	28	2.4	60,982	10	1.5	13,612	.8	48,785	2,979	10,345	26,136
17-15	1.21	B-3	20	2.4	940	64	1.5	1,881	.8	752	208	494	2,258
17-16	9.17	B-1	20	2.4	7,101	60	1.5	13,315	.2	1,420	1,574	3,551	17,050
17-17	10.00	R-0	24	2.4	9,291	40	1.5	9,678	.8	7,433	1,716	3,097	18,588
17-18	15.15	R-3	24	2.4	14,080	30	1.5	11,000	.8	11,264	2,738	3,227	29,742
17-19	49.39	R-2	24	2.4	45,897	15	1.5	17,928	.8	36,717	1,811	9,322	36,336
17-20	153.99	R-1	28	2.4	166,955	10	1.5	37,267	.8	133,564	8,156	28,323	71,556
17-21	43.06	R-1	28	2.4	46,684	10	1.5	10,421	.8	37,347	2,281	7,920	20,009
17-22	63.64	R-2	24	2.4	59,136	15	1.5	23,100	.8	47,309	2,333	12,012	46,818
PAGE TOTAL:					914,555			708,674		725,653	166,223	248,048	1,292,961

TABLE A-1.9 - Anchorage Estimated Sand and Gravel Use, Private Development

(1) ZONING SHEET[1]	(2) LAND AREA,AC	(3) ZONING	(4) STREETS M[2]	(5) D[3]	(6) VOLUME[4]	(7) PARKING/DRIVEWAYS M[5]	(8) D[3]	(9) VOLUME	(10) UTILITIES M[6]	(11) VOLUME	(12) CONCRETE[7] VOLUME	(13) ASPHALT/ BASE[8]	(14) BUILDING BACKFILL[9]
17-23	20.00	R-2A	24	2.4	18,586	15	1.5	7,260	.8	3,717	741	3,775	14,222
17-24	10.00	R-1	28	2.4	10,842	10	1.5	2,420	.8	2,168	530	1,839	4,647
17-25	10.00	R-5	24	2.4	9,293	20	1.5	4,840	.8	1,859	669	2,130	3,388
17-26	40.00	R-1	28	2.4	37,171	10	1.5	9,680	.8	7,434	2,118	6,582	18,587
17-27	20.29	R-1	28	2.4	22,002	10	1.5	4,911	.8	4,400	1,075	3,732	9,430
17-28	20.59	R-2	24	2.4	19,132	15	1.5	7,473	.8	3,826	755	3,886	15,146
17-29	5.00	R-3	24	2.4	4,646	30	1.5	3,630	.8	929	904	1,065	9,815
17-30	5.00	B-3	20	2.4	3,872	64	1.5	7,744	.8	774	858	2,033	9,296
17-31	55.00	R-1	28	2.4	59,629	10	1.5	13,310	.8	11,926	2,913	10,116	25,557
17-32	19.24	R-3	24	2.4	17,882	30	1.5	13,968	.8	3,576	3,477	4,098	37,772
17-33	22.41	B-3SL	20	2.4	17,351	64	1.5	34,702	.8	3,470	3,846	9,109	41,658
--	160.00	R-8	4	2.4	24,780	0	--	--	0	--	456	--	0
--	904.00	R-9	6	2.4	210,017	0	--	--	0	--	5,156	--	0
PAGE TOTALS:					455,203			109,938		44,079	23,498	48,365	189,518
ANCHORAGE TOTALS:					5,699,477			2,933,064		3,930,807	618,240	1,189,650	6,244,508

TABLE A-1.11 - FOOTNOTES

1. Municipality of Anchorage, Planning Department, zoning sheet numbers.
2. Road area multiplier, as a percentage of land cover.
3. Street gravel base thickness based on RSS frost design criteria currently used by the Department of Public Works.
4. All quantities are cubic yards in-place volume.
5. Parking areas and driveways multiplier, as a percentage of land cover.
6. Utilities gravel use multiplier, as a fraction of street volume of gravel; i.e., M = .8 means .8 X volume of gravel used for street subbase equals volume of gravel needed for utilities construction.
7. Concrete demand unit in cubic feet per acre, see Table A1.12.
8. Volume of gravel for asphalt concrete pavement including 2" leveling course.
9. Building backfill, see Table A1.13.

NOTE: The following equations apply:

Column

$$\textcircled{6} = 2 \times \textcircled{4} \times 5 \; \frac{43560}{27}$$

$$9 = 2 \times 7 \times 8 \; \frac{43560}{27}$$

$$11 = 6 \times 10$$

$$\textcircled{12} = \frac{9 \times \textcircled{2}}{27}$$

$$\textcircled{13} = 2 \times \frac{(4 + 7)}{100} \times 0.3 \times \frac{43560}{27}$$

$$14 = \frac{2 \times 6}{27}$$

Where:

$\textcircled{2}$ relates to Table A-1.1 to 1.10, Column 2

$\boxed{9}$ relates to Table A-1.12, Column 9

$\triangle 6$ relates to Table A-1.13, Column 6

TABLE A-1.12 - Estimated Average Concrete Demand

1	2	3	4	5	6	7	8	9
ZONING	FND.[1] LENGTH, L.F.	CONCRETE VOL./L.F.[2]	CONCRETE VOL./DU[3]	TYPICAL SLAB, S.F.	SLAB THICKNESS	CONCRETE VOL./DU	NO. DU[4]	TOTAL UNIT VOL./ACRE[5]
R-1	140	1.10	154	400	0.33	132	5.0	1430
R-1A	160	1.10	176	400	0.33	132	3.5	1078
R-2	180	1.10	198	**	**	198	5.0	990
R-2A	200	1.10	220	200	0.33	66	3.5	1001
R-3	460	1.10	506	13250	0.33	--	--	4879
R-4	515	1.10	566	16533	0.33	--	--	6028
R-5	271	1.10	298	4574	0.33	--	--	1807
R-6	160	1.10	176	500	0.33	165	2.0	341
R-7	160	1.10	176	500	0.33	165	2.0	682
R-8	200	1.10	220	500	0.33	165	0.2	77
R-9	200	1.10	220	500	0.33	165	0.4	154
B-1,2,3,4	448	1.10	493	12550	0.33	--	--	4635
I-1,2,3	472	1.10	520	13940	0.33	--	--	5120

---

1 Typical lineal feet of foundation wall.

2 Average volume of wall per lineal feet, C.F./L.F.

3 Estimated volume of concrete per density unit, C.F./D.U.

4 Number of density units per acre, D.U./Acre.

5 Estimated volume of concrete per acre of land, C.F./Acre.

** Carports common, slabs rarely used.

TABLE A-1.13 - Estimated Average Building Backfill Quantities

1 ZONING	2 PERCENT USABLE LAND	3 TYPICAL PERCENT BLDG. COVER	4 AVERAGE BLDG. PAD (SQUARE FT.)	5 AVERAGE DEPTH OF FILL (FT.)	6 UNIT VOLUME GRAVEL FILL, CUBIC FT./AC.
R-1	72	20	6273	2.0	12,546
R-1A	72	18	5645	2.0	11,290
R-2	76	30	9932	2.0	19,864
R-2A	76	29	9600	2.0	19,200
R-3	76	40	13250	4.0	53,000
R-4	76	50	16553	4.0	66,212
R-5	70	15	4574	2.0	9,148
R-6	--	3	1307	2.0	2,615
R-7	80	8	2788	2.0	5,576
R-8	--	--	--	--	--
R-9	--	--	--	--	--
B-1	80	36	12550	4.0	50,200
B-2	80	36	12550	4.0	50,200
B-3,4	80	36	12550	4.0	50,200
I-1,2,3	80	40	13940	4.0	55,760

APPENDIX J

AREA ASSESSMENT MATRICES

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SEATTLE, WA. ANCHORAGE, AK.

AREA ASSESSMENT MATRIX

ANCHORAGE BOWL

ANCHORAGE NATURAL RESOURCES (GRAVEL) EXTRACTION MANAGEMENT STUDY

JUNE, 1982

IMPACTS / BENEFITS ASSESSMENT

PHYSICAL CHEMICAL IMPACTS BENEFITS

LAND
1.1 MINERAL RESOURCES DEPLETION/BENEFIT
1.2 CONSTRUCTION MATERIALS DEPLETION/BENEFIT
1.3 SOILS - IMPROVEMENT/IMPACT BEARING ☐ TOP SOIL ☐
1.4 LANDFORM - IMPROVEMENT/IMPACT
1.5 OTHER UNIQUE FEATURES BENEFIT/IMPACT
1.6 SEISMIC SENSITIVITY
1.7 STABILITY (SLIDES, SLUMPS)

WATER RESOURCES
2.1 SURFACE STREAMS & LAKES QUALITY IMPROVEMENT/IMPACT
2.2 GROUND WATER - IMPROVEMENT/IMPACT
2.3 SNOWMELT & ACCUMULATION, GLACIATION & ICING - BENEFIT/IMPACT
2.4 SURFACE DRAINAGE - BENEFIT/IMPACT
2.5 FLOODING
2.6 EROSION AND SEDIMENTATION
2.7 SOLUTION/SORPTION (ION EXCHANGE COMPLEXING)

AIR QUALITY
3.1 GASES & PARTICULATE MATTER
3.2 MICRO/MACRO CLIMATE
3.3 TEMPERATURE

BIOLOGICAL IMPACTS BENEFITS

FLORA
1.1 TREES - ENHANCE/DESTROY
1.2 SHRUBS - ENHANCE/DESTROY
1.3 CROPS - ENHANCE/DESTROY
1.4 WILDLIFE HABITAT - ENHANCE/DESTROY
1.5 MICROFLORA - ENHANCE/DESTROY
1.6 AQUATIC PLANTS - ENHANCE/DESTROY
1.7 ENDANGERED SPECIES - ENHANCE/DESTROY
1.8 BARRIERS - ENHANCE/DESTROY
1.9 CORRIDORS - ENHANCE/DESTROY

FAUNA
2.1 BIRDS - IMPACT/ENHANCE
2.2 LAND ANIMALS, GAME
2.3 FISH & SHELLFISH - IMPACT/ENHANCE
2.4 BENTHIC ORGANISMS - IMPACT/ENHANCE
2.5 INSECTS - IMPACT/ENHANCE
2.6 MICROFAUNA - IMPACT/ENHANCEMENT
2.7 ENDANGERED SPECIES - IMPACT/ENHANCEMENT
2.8 BARRIERS - ENHANCE/DESTROY
2.9 CORRIDORS - ENHANCE/DESTROY

CULTURAL IMPACTS BENEFITS

LAND USE, PRESENT
1.1 WILDERNESS & OPEN SPACES - ENHANCE/IMPACT
1.2 WETLANDS - ENHANCE/IMPACT
1.3 GRAZING/AGRICULTURE - ENHANCE/IMPACT
1.4 RESIDENTIAL - ENHANCE/IMPACT
1.5 COMMERCIAL - ENHANCE/IMPACT
1.6 INDUSTRIAL - ENHANCE/IMPACT

LAND USE, FUTURE
2.1 WILDERNESS & OPEN SPACES ENHANCE/IMPACT
2.2 WETLANDS - ENHANCE/IMPACT
2.3 GRAZING/AGRICULTURE - ENHANCE/IMPACT
2.4 RESIDENTIAL - ENHANCE/IMPACT
2.5 COMMERCIAL - ENHANCE/IMPACT
2.6 INDUSTRIAL - ENHANCE/IMPACT

AESTHETICS AND HUMAN INTEREST
3.1 SCENIC VIEWS & VISTAS - ENHANCE/IMPACT
3.2 WILDERNESS QUALITIES - ENHANCE/IMPACT
3.3 OPEN SPACE QUALITIES - ENHANCE/IMPACT
3.4 LANDSCAPE - ENHANCE/IMPACT
3.5 PARKS & RESERVES IN CLOSE PROXIMITY NAME
3.6 HISTORICAL OR ARCHAEOLOGICAL SITES AND OBJECTS
3.7 VISIBILITY FROM MAJOR STREETS OR HIGHWAYS - IMPACT
3.8 VISIBILITY FROM RESIDENTIAL AREAS
3.9 UNIQUE ECOSYSTEMS

TRANSPORTATION
4.1 CIRCULATION/ACCESS ENHANCE/IMPACT
4.2 LOCAL RESIDENTIAL - IMPACT
4.3 STREET MAINTENANCE - IMPACT
4.4 UTILITY NETWORK - IMPACT

RECREATION
5.1 HUNTING - IMPACT/ENHANCEMENT
5.2 FISHING - IMPACT/ENHANCEMENT
5.3 BOATING - IMPACT/ENHANCEMENT
5.4 SWIMMING - IMPACT/ENHANCEMENT
5.5 CAMPING, HIKING, PICNIC RESORTS - IMPACT, ENHANCEMENT
5.6 ALL TERRAIN VEHICLES/SNOW MACHINES

PUBLIC STATUS
6.1 CULTURAL PATTERNS (LIFE STYLE) IMPACT/ENHANCEMENT
6.2 HEALTH & SAFETY - IMPACT/ENHANCEMENT
6.3 EMPLOYMENT - IMPACT/ENHANCEMENT
6.4 POPULATION DENSITY, PRESENT, IMPACT/ENHANCE
6.5 POPULATION DENSITY, FUTURE, IMPACT/ENHANCE
6.6 PUBLIC NUISANCE/HAZARD

NATURAL RESOURCE / EXTRACTION SITES

SITE NO.	DESCRIPTION SUMMARY
1233-1	ANCHORAGE SAND & GRAVEL (1ST & ORCA) GRAVEL PIT, 10 ACRES, ACTIVE, 100,000 TONS RESERVES PENDING UTILITY RELOCATIONS, ON SITE CONCRETE MIX PLANT, APPROVED GRADING AND RESTORATION IS ADEQUATE
1521-1	POINT WORONZOF, 20 ACRES FORMER D.O.T. PIT, PRESENTLY ABANDONED, SOME EVIDENCE OF RECENT MINOR ACTIVITY, EXTENSIVELY USED BY THE PUBLIC AS A VIEW SITE AND ACCESS TO THE BEACH, THE SITE IS 80+ FEET ABOVE THE BEACH, SEVERE SLOPE EROSION, PUBLIC SAFETY PROBLEM, SITE RESTORATION PLAN IS NEEDED TO INCLUDE PUBLIC SAFETY MEASURES
2028-1	CENTRAL PAVING PRODUCTS PLANT, STORAGE SITE FOR SAND AND GRAVEL HAULED BY TRAIN FROM MATANUSKA VALLEY, MAX. CAPACITY 6,400 TONS/DAY, SITE PLANNING IS NEEDED, SPECIFIC MITIGATION MEASURES SHOULD INCLUDE DUST CONTROL AND FENCING
2130-1	ALAGCO PLANT, CONCRETE AND CONCRETE PRODUCTS, 68TH & "C" STREET, MATERIAL STORAGE SITE, MAX CAPACITY 4,500 TONS/DAY, MATERIAL HAULED BY TRAIN FROM MATANUSKA VALLEY, MITIGATION SHOULD INCLUDE NEAT MATERIALS , STORAGE MANAGEMENT, DUST CONTROL AND COMPLETE FENCING
2135-1	LORE ROAD, NORTH, 10 ACRES, PRESENTLY UNCONTROLLED FILLING, LAND FOR SALE INACTIVE, NO RESTORATION PLAN ON FILE, RECOMMEND CONTROLLED FILLING
2234-1	LORE ROAD, AT SPRUCE STEEET, 12 ACRES, PRESENTLY INACTIVE, SOME UNCONTROLED FILLING, MINOR EROSION PROBLEMS, MATERIAL STOCK PILES ADJACENT TO SPRUCE STREET, 60' (1.5:1) CUT BANKS AT SPRUCE AND LORE, RESTORATION PLAN IS ADEQUATE, HOWEVER PROVISIONS SHOULD BE MADE FOR CONTROLLED FILL
2235-1	LORE ROAD, SOUTH OF, 5 ACRES, PRESENTLY INACTIVE, SOME UNCONTROLLED FILLING, MINOR EROSION, GRADING RECOMMENDED FOR AESTHETIC PURPOSES ONLY
2533-1	LAKE OTIS PARKWAY, WEST OF, BETWEEN O'MALLEY AND ABBOTT, 40 ACRES, PLANNED FOR RESIDENTIAL DEVELOPMENT, EXTENSIVE UNCONTROLLED FILLING AND DUMPING DESPITE WARNING SIGNS, NO SPECIFIC MITIGATION REQUIRED PRIOR TO DEVELOPMENT, ENGINEERED FOUNDATIONS RECOMMENDED IN FILLING AREAS
2533-2	LAKE OTIS PARKWAY AND O'MALLEY ROAD, N.W. CORNER OF, 10 ACRES, ABANDONED, MINOR EROSION, NO FUTURE PLANS, TOP SOIL AND SEEDING RECOMMENDED FOR AESTHETIC PURPOSES
2631-1	ANCHORAGE SAND & GRAVEL, KLATT ROAD STORAGE AND PROCESSING SITE, 20 ACRES, CONCRETE MIX PLANT AND PRODUCTS, MATERIAL HAUL FROM MATANUSKA VALLEY, MAX CAPACITY 6,400 TONS/DAY, NO ON-SITE EXCAVATION, MITIGATION SHOULD INCLUDE NEAT MATERIALS STORAGE MANAGEMENT, DUST CONTROL, AND COMPLETE FENCING
2631-2	OLD SEWARD HIGHWAY, WEST OF, AT O'MALLEY ROAD, 20 ACRES, DEPLETED, ABANDONED, EYE SORE, MINOR DUMPING, NEEDS RESTORATION AND/OR RECREATION PLANNING
2634-1	PIONEER SAND AND GRAVEL, CANGE STREET AND KLATT ROAD, 80 ACRES, ACTIVE CONDITIONAL USE PERMIT EXPIRES DEC. 1982, APPROVED GRADING AND RESTORATION PLAN IS ADEQUATE, ON-SITE SEDIMENT POND, GRADING PLAN ON FILE IS ADEQUATE, SEDIMENT POND NEEDS MAINT., THE SITE IS CURRENTLY POSTED BUT NOT FENCED, EXCAVATION PERMIT EXPIRES 1986

LEGEND — EACH BOX DENOTES IMPACT OR BENEFIT IN THE UPPER HALF. BENEFITS ARE INDICATED WITH A PLUS (+) SIGN, IMPACTS WITH A MINUS (-) SIGN. THE LOWER HALF OF THE BOX INDICATES RELATIVE IMPORTANCE FOR EACH ITEM.

BENEFITS(+) IMPACTS(-) 0 = ☐ 2 = ± 4 = ± 6 = ± 8 = ± 10 = ±

IMPORTANCE 0 = ☐ 2 = ▒ 4 = ▒ 6 = ▓ 8 = ■ 10 = ■

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S&S engineers, inc. A JOINT VENTURE
SEATTLE, WA. ANCHORAGE, AK.

AREA ASSESSMENT MATRIX

TURNAGAIN ARM

ANCHORAGE NATURAL RESOURCES (GRAVEL) EXTRACTION MANAGEMENT STUDY

JUNE, 1982

IMPACTS / BENEFITS ASSESSMENT

PHYSICAL CHEMICAL IMPACTS BENEFITS

LAND
- 1.1 MINERAL RESOURCES [illegible] DEPLETION/BENEFIT
- 1.2 CONSTRUCTION MATERIALS DEPLETION/BENEFIT
- 1.3 SOILS - IMPROVEMENT/IMPACT BEARING ☐ TOP SOIL ☐
- 1.4 LANDFORM - IMPROVEMENT/IMPACT
- 1.5 OTHER UNIQUE FEATURES BENEFIT/IMPACT
- 1.6 SEISMIC SENSITIVITY
- 1.7 STABILITY (SLIDES, SLUMPS)

WATER RESOURCES
- 2.1 SURFACE STREAMS & LAKES QUALITY IMPROVEMENT/IMPACT
- 2.2 GROUND WATER - IMPROVEMENT/IMPACT
- 2.3 SNOW (MELT & ACCUMULATION), GLACIATION & ICING - BENEFIT/IMPACT
- 2.4 SURFACE DRAINAGE - BENEFIT/IMPACT
- 2.5 FLOODING
- 2.6 EROSION AND SEDIMENTATION
- 2.7 SOLUTION/SORPTION (ION EXCHANGE COMPLEXING)

AIR QUALITY
- 3.1 GASES & PARTICULATE MATTER
- 3.2 MICRO/MACRO CLIMATE
- 3.3 TEMPERATURE

BIOLOGICAL IMPACTS BENEFITS

FLORA
- 1.1 TREES - ENHANCE/DESTROY
- 1.2 SHRUBS - ENHANCE/DESTROY
- 1.3 CROPS - ENHANCE/DESTROY
- 1.4 WILDLIFE HABITAT - ENHANCE/DESTROY
- 1.5 MICROFLORA - ENHANCE/DESTROY
- 1.6 AQUATIC PLANTS - ENHANCE/DESTROY
- 1.7 ENDANGERED SPECIES - ENHANCE/DESTROY
- 1.8 BARRIERS - ENHANCE/DESTROY
- 1.9 CORRIDORS - ENHANCE/DESTROY

FAUNA
- 2.1 BIRDS - IMPACT/ENHANCE
- 2.2 LAND ANIMALS, NAME
- 2.3 FISH & SHELLFISH - IMPACT/ENHANCE
- 2.4 BENTHIC ORGANISMS - IMPACT/ENHANCE
- 2.5 INSECTS - IMPACT/ENHANCE
- 2.6 MICROFAUNA - IMPACT/ENHANCEMENT
- 2.7 ENDANGERED SPECIES - IMPACT/ENHANCEMENT
- 2.8 BARRIERS - ENHANCE/DESTROY
- 2.9 CORRIDORS - ENHANCE/DESTROY

CULTURAL IMPACTS BENEFITS

LAND USE, PRESENT
- 1.1 WILDERNESS & OPEN SPACES - ENHANCE/IMPACT
- 1.2 WETLANDS - ENHANCE/IMPACT
- 1.3 GRAZING/AGRICULTURE - ENHANCE/IMPACT
- 1.4 RESIDENTIAL - ENHANCE/IMPACT
- 1.5 COMMERCIAL - ENHANCE/IMPACT
- 1.6 INDUSTRIAL - ENHANCE/IMPACT

LAND USE, FUTURE
- 2.1 WILDERNESS & OPEN SPACES ENHANCE/IMPACT
- 2.2 WETLANDS - ENHANCE/IMPACT
- 2.3 GRAZING/AGRICULTURE - ENHANCE/IMPACT
- 2.4 RESIDENTIAL - ENHANCE/IMPACT
- 2.5 COMMERCIAL - ENHANCE/IMPACT
- 2.6 INDUSTRIAL - ENHANCE/IMPACT

AESTHETICS AND HUMAN INTEREST
- 3.1 SCENIC VIEWS & VISTAS - ENHANCE/IMPACT
- 3.2 WILDERNESS QUALITIES - ENHANCE/IMPACT
- 3.3 OPEN SPACE QUALITIES - ENHANCE/IMPACT
- 3.4 LANDSCAPE - ENHANCE/IMPACT
- 3.5 PARKS & RESERVES IN CLOSE PROXIMITY [illegible] NAME
- 3.6 HISTORICAL OR ARCHAEOLOGICAL SITES AND OBJECTS
- 3.7 VISIBILITY FROM MAJOR STREETS OR HIGHWAYS - IMPACT
- 3.8 VISIBILITY FROM RESIDENTIAL AREAS
- 3.9 UNIQUE ECOSYSTEMS

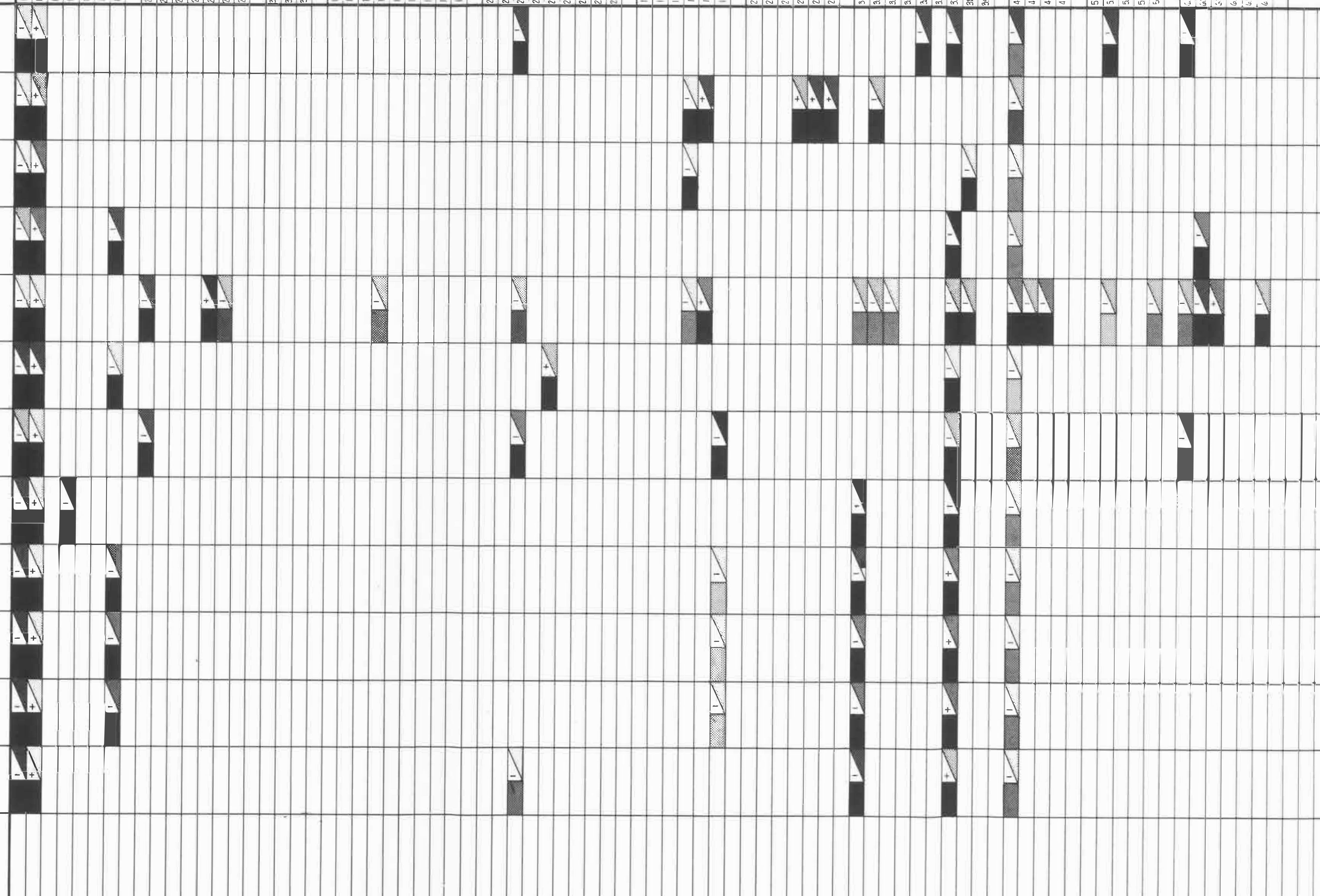
TRANSPORTATION
- 4.1 CIRCULATION/ACCESS ENHANCE/IMPACT
- 4.2 LOCAL RESIDENTIAL - IMPACT
- 4.3 STREET MAINTENANCE - IMPACT
- 4.4 UTILITY NETWORK - IMPACT

RECREATION
- 5.1 HUNTING - IMPACT/ENHANCEMENT
- 5.2 FISHING - IMPACT/ENHANCEMENT
- 5.3 BOATING - IMPACT/ENHANCEMENT
- 5.4 SWIMMING - IMPACT/ENHANCEMENT
- 5.5 CAMPING, HIKING, PICNIC RESORTS - IMPACT/ENHANCEMENT

PUBLIC STATUS
- 6.1 [illegible] PATTERNS, LIFE STYLE IMPACT/ENHANCEMENT
- 6.2 HEALTH & SAFETY - IMPACT/ENHANCEMENT
- 6.3 [illegible] - IMPACT/ENHANCEMENT
- 6.4 [illegible] PRESENT, IMPACT/ENHANCE
- 6.5 POPULATION DENSITY, FUTURE, IMPACT/ENHANCE
- 6.6 PUBLIC NUISANCE / HAZARD

NATURAL RESOURCE / EXTRACTION SITES

SITE NO.	DESCRIPTION SUMMARY
TA-1	INDIAN CREEK, 5.0 ACRES, STATE MS 31-2-005-1 AND 31-2-391-1, PRESENTLY ABANDONED, LESS THAN 5,000 C.Y. REMAINING. NO SPECIFIC MITIGATION REQUIRED.
TA-2	0.15 MILES EAST OF BIRD CREEK, 11.5 ACRES, 400 FEET NORTH OF SEWARD HIGHWAY, STATE MS 31-2-042-1, PRESENTLY USED AS A STORAGE SITE FOR WILDER CONSTRUCTION, APPROX. 23,000 C.Y. REMAINING. REQUIRES OPERATION/RESTORATION PLAN.
TA-3	0.3 MILES EAST OF BIRD CREEK, 2.5 ACRES, 300 FEET NORTH OF SEWARD HIGHWAY, PRIVATE, TERMINATION 12-31-82, RESTORATION 9-1-83, 30,000 TO 40,000 C.Y. AVAILABLE (EST.). APPROVED RESTORATION PLAN PROVIDES ADEQUATE MITIGATION MEASURES.
TA-4	APPROX. MP 98 SEWARD HIGHWAY, 135.0 ACRES, STATE MS 31-2-021-1 (75.0 ACRES, ARR HAS PERMIT) AND MS 31-2-024-1 (60.0 ACRES, DOT HAS PERMIT), NOT A VIABLE FUTURE SOURCE. NO MITIGATION REQUIRED.
TA-5	GLACIER CREEK, 100 ACRES, DNR ISSUES PERMITS TO PRIVATE PARTIES, 16,000 C.Y. PER YEAR PRESENTLY EXCAVATED BY PERMIT. RECOMMENDED FUTURE SOURCE, AVERAGE ESTIMATED RECHARGE CAPACITY IS 80,000 TONS /DAY (42,300 C.Y./DAY) NOT FIELD VERIFIED. MITIGATION SHOULD INCLUDE CONTROLLED ACCESS DURING SCHOOL HOURS, OR ACCESS BY WAY OF AIRPORT ROAD.
TA-6	0.5 MILE EAST OF GIRWOOD, 0.25 MILE SOUTH OF SEWARD HIGHWAY, 15.0 ACRES, STATE MS 31-2-027-1, (DOT) PROVIDES MAINTENANCE SAND FOR GIRDWOOD, LESS THAN 5,000 C.Y. AVAILABLE PER YEAR. MITIGATION NOT REQUIRED.
TA-7	PORTAGE CREEK, 5.0 ACRES STATE MS 31-2-037-1 AND MS 31-2-033-1, USED FOR RECONSTRUCTION OF SEWARD HIGHWAY, PRESENTLY ABANDONED, NOT VIABLE FUTURE SOURCE.
TA-8	BIRD POINT, 10.0 ACRES, RIP-RAP STONE QUARRY, 20,000 C.Y. PROVEN. REQUIRES MINING PLAN.
TA-9	APPROX. MP 92 SEWARD HIGHWAY, 15 ACRES, STATE MS 31-2-023-1, NO ACTIVITY NOTED, NOT A VIABLE FUTURE SOURCE.
TA-10	PETERSON CREEK, 15.0 ACRES, STATE MS 31-2-012-1 FRACTURED BEDROCK, INACCESSIBLE, PRESENTLY ABANDONED, NOT A VIABLE FUTURE SOURCE.
TA-11	APPROX. MP 81.8 SEWARD HIGHWAY, 10.0 ACRES, STATE MS 31-2-025-1 AND 31-2-031-1, FRACTURED BEDROCK, INACCESSIBLE, PRESENTLY ABANDONED.
TA-12	PLACER RIVER, PRESENTLY NO OPERATION, NOT A VIABLE FUTURE SOURCE.



LEGEND — EACH BOX DENOTES IMPACT OR BENEFIT IN THE UPPER HALF. BENEFITS ARE INDICATED WITH A PLUS (+) SIGN, IMPACTS WITH A MINUS (-) SIGN. THE LOWER HALF OF THE BOX INDICATES RELATIVE IMPORTANCE FOR EACH ITEM.

BENEFITS(+) IMPACTS(-) 0= 2= 4= 6= 8= 10=

IMPORTANCE 0= 2= 4= 6= 8= 10=

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S&S engineers, inc. A JOINT VENTURE
SEATTLE, WA. ANCHORAGE, AK.

AREA ASSESSMENT MATRIX

EAGLE RIVER / EKLUTNA

ANCHORAGE NATURAL RESOURCES (GRAVEL) EXTRACTION MANAGEMENT STUDY

JUNE, 1982

IMPACTS / BENEFITS ASSESSMENT

PHYSICAL CHEMICAL IMPACTS BENEFITS

LAND
- 1.1 MINERAL RESOURCES DEPLETION/BENEFIT
- 1.2 CONSTRUCTION MATERIALS DEPLETION/BENEFIT
- 1.3 SOILS - IMPROVEMENT/IMPACT BEARING ☐ TOP SOIL ☐
- 1.4 LANDFORM - IMPROVEMENT/IMPACT
- 1.5 OTHER UNIQUE FEATURES BENEFIT/IMPACT
- 1.6 SEISMIC SENSITIVITY
- 1.7 STABILITY (SLIDES, SLUMPS)

WATER RESOURCES
- 2.1 SURFACE STREAMS & LAKES QUALITY IMPROVEMENT/IMPACT
- 2.2 GROUND WATER - IMPROVEMENT/IMPACT
- 2.3 SNOWMELT & ACCUMULATION, GLACIATION & ICING - BENEFIT/IMPACT
- 2.4 SURFACE DRAINAGE - BENEFIT/IMPACT
- 2.5 FLOODING
- 2.6 EROSION AND SEDIMENTATION
- 2.7 SOLUTION/SORPTION (ION EXCHANGE COMPLEXING)

AIR QUALITY
- 3.1 GASES & PARTICULATE MATTER
- 3.2 MICRO/MACRO CLIMATE
- 3.3 TEMPERATURE

BIOLOGICAL IMPACTS BENEFITS

FLORA
- 1.1 TREES - ENHANCE/DESTROY
- 1.2 SHRUBS - ENHANCE/DESTROY
- 1.3 CROPS - ENHANCE/DESTROY
- 1.4 WILDLIFE HABITAT - ENHANCE/DESTROY
- 1.5 MICROFLORA - ENHANCE/DESTROY
- 1.6 AQUATIC PLANTS - ENHANCE/DESTROY
- 1.7 ENDANGERED SPECIES - ENHANCE/DESTROY
- 1.8 BARRIERS - ENHANCE/DESTROY
- 1.9 CORRIDORS - ENHANCE/DESTROY

FAUNA
- 2.1 BIRDS - IMPACT/ENHANCE
- 2.2 LAND ANIMALS, NAME
- 2.3 FISH & SHELLFISH - IMPACT/ENHANCE
- 2.4 BENTHIC ORGANISMS - IMPACT/ENHANCE
- 2.5 INSECTS - IMPACT/ENHANCE
- 2.6 MICROFAUNA - IMPACT/ENHANCEMENT
- 2.7 ENDANGERED SPECIES - IMPACT/ENHANCEMENT
- 2.8 BARRIERS - ENHANCE/DESTROY
- 2.9 CORRIDORS - ENHANCE/DESTROY

CULTURAL IMPACTS BENEFITS

LAND USE, PRESENT
- 1.1 WILDERNESS & OPEN SPACES - ENHANCE/IMPACT
- 1.2 WETLANDS - ENHANCE/IMPACT
- 1.3 GRAZING/AGRICULTURE - ENHANCE/IMPACT
- 1.4 RESIDENTIAL - ENHANCE/IMPACT
- 1.5 COMMERCIAL - ENHANCE/IMPACT
- 1.6 INDUSTRIAL - ENHANCE/IMPACT

LAND USE, FUTURE
- 2.1 WILDERNESS & OPEN SPACES ENHANCE/IMPACT
- 2.2 WETLANDS - ENHANCE/IMPACT
- 2.3 GRAZING/AGRICULTURE - ENHANCE/IMPACT
- 2.4 RESIDENTIAL - ENHANCE/IMPACT
- 2.5 COMMERCIAL - ENHANCE/IMPACT
- 2.6 INDUSTRIAL - ENHANCE/IMPACT

AESTHETICS AND HUMAN INTEREST
- 3.1 SCENIC VIEWS & VISTAS - ENHANCE/IMPACT
- 3.2 WILDERNESS QUALITIES - ENHANCE/IMPACT
- 3.3 OPEN SPACE QUALITIES - ENHANCE/IMPACT
- 3.4 LANDSCAPE - ENHANCE/IMPACT
- 3.5 PARKS & RESERVES IN CLOSE PROXIMITY NAME
- 3.6 HISTORICAL OR ARCHAEOLOGICAL SITES AND OBJECTS
- 3.7 VISIBILITY FROM MAJOR STREETS OR HIGHWAYS - IMPACT
- 3.8 VISIBILITY FROM RESIDENTIAL AREAS
- 3.9 UNIQUE ECOSYSTEMS

TRANSPORTATION
- 4.1 CIRCULATION/ACCESS ENHANCE/IMPACT
- 4.2 LOCAL RESIDENTIAL - IMPACT
- 4.3 STREET MAINTENANCE - IMPACT
- 4.4 UTILITY NETWORK - IMPACT

RECREATION
- 5.1 HUNTING - IMPACT/ENHANCEMENT
- 5.2 FISHING - IMPACT/ENHANCEMENT
- 5.3 BOATING - IMPACT/ENHANCEMENT
- 5.4 SWIMMING - IMPACT/ENHANCEMENT
- 5.5 CAMPING, HIKING, PICNIC RESORTS - IMPACT/ENHANCEMENT

PUBLIC STATUS
- 6.1 CULTURAL PATTERNS (LIFE STYLE) IMPACT/ENHANCEMENT
- 6.2 HEALTH & SAFETY - IMPACT/ENHANCEMENT
- 6.3 EMPLOYMENT - IMPACT/ENHANCEMENT
- 6.4 POPULATION DENSITY, PRESENT, IMPACT/ENHANCE
- 6.5 POPULATION DENSITY, FUTURE, IMPACT/ENHANCE
- 6.6 PUBLIC NUISANCE / HAZARD

NATURAL RESOURCE / EXTRACTION SITES

SITE NO.	DESCRIPTION SUMMARY
ER-1	ARTILLERY ROAD AND GLENN HIGHWAY, HIGHLY VISIBLE FROM GLENN HIGHWAY ADJACENT TO EAGLE RIVER OVERPASS, PRESENTLY INACTIVE, 1,000,000 CUBIC YARDS REMAINING, RECOMMENDED AS A VIABLE SOURCE AFTER OPERATIONS AND RESTORATION PLANNING
ER-2	N. BIRCHWOOD LOOP AND BEVERLY DRIVE, 5 ACRES, PRESENTLY INACTIVE, RESTORATION PLAN PROVIDES MITIGATION MEASURES AND SHOULD BE FOLLOWED CLOSELY, DISTANCE FROM MINK CREEK MITIGATES EROSION IMPACT, NOT A VIABLE FUTURE SOURCE, REQUIRES RESTORATION
ER-3	MOOSE HORN BUS GARAGE, OLD GLENN HIGHWAY, CHUGIAK, PRESENTLY INACTIVE, QUANTITY OF RESERVES UNKNOWN, NO INFORMATION AVAILABLE
ER-4	KLONDIKE, OLD GLENN HIGHWAY, CHUGIAK, 100 ACRES, ACTIVE, MATERIAL FOR CONCRETE AND OTHER USES, ON-SITE CONCRETE MIX PLANT, ADEQUATE MATERIAL FOR INDEFINITE CONCRETE PRODUCTION, APPROVED OPERATION AND RESTORATION PLAN PROVIDES ADEQUATE MITIGATION MEASURES
ER-5	STEPHENS AND SONS MATERIAL SITE, OLD GLENN HIGHWAY, LITTLE PETERS CREEK, CHUGIAK, PRESENTLY INACTIVE, QUANTITY OF RESERVES NOT VERIFIED, APPROVED OPERATION AND RESTORATION PLAN PROVIDES ADEQUATE MITIGATION MEASURES
ER-6	NORTHERN STEEL, OLD GLENN HIGHWAY, LITTLE PETERS CREEK, CHUGIAK, 40 ACRES, ACTIVE, 1,500,000 CUBIC YARDS AVAILABLE RESERVES, APPROVED RESTORATION PLAN PROVIDES ADEQUATE MITIGATION MEASURES
ER-7	CENTRAL PAVING PRODUCTS (ROGERS AND BABLER), CHUGIAK, OLD GLENN HIGHWAY, 40 ACRES, ACTIVE, 1,500,000 CUBIC YARDS ALL PURPOSE MATERIAL AVAILABLE RESERVES, ON-SITE ASPHALT PLANT, APPROVED OPERATION AND RESTORATION PLAN PROVIDES ALL NEEDED MITIGATION MEASURES
ER-8	IZAAK WALTON LEAGUE GUN RANGE, WEST OF BIRCHWOOD AIRPORT, OPERATIONS TO BE COMPLETE THIS YEAR, 40,000 C.Y. PERMITTED
ER-9	EKLUTNA RIVER FLOOD PLAIN- MBE GRAVEL COMPANY, PRESENTLY INACTIVE, POSSIBLE FUTURE SOURCE, RECHARGE ANALYSIS ESTIMATED AVERAGE IS 50,000 TONS/DAY RECHARGE CAPACITY BASED ON ASSUMED DATA, FIELD VERIFICATION IS NECESSARY
ER-10	ALASKA RAILROAD RESERVES - ROGERS & BABLER OPERATOR, 1,500,000 C.Y. PIT-RUN GRAVEL (EXCELLENT QUALITY) REMAINING AFTER CURRENT CONTRACT ENDS, POTENTIAL FUTURE SOURCE, HOWEVER OWNERSHIP & MINING RIGHTS CONFLICTS EXIST

SITE NO.	Land 1.1	Land 1.2	Land 1.4	Land 1.7	Water 2.1	Water 2.4	Water 2.6	Air 3.1	Flora 1.1	Fauna 2.3	Land Use Present 1.5	Land Use Future 2.4	Land Use Future 2.5	Land Use Future 2.6	Aesthetics 3.7	Aesthetics 3.8	Transportation 4.1	Recreation 5.2	Public Status 6.2	Public Status 6.6
ER-1	−	+	+										+	+	−	−	−			
ER-2				−											−	−			+	
ER-3				−							+				−	−			−	
ER-4	−	+		−	−			−	−			−			−	−	−		−	−
ER-5				■											■	■			■	
ER-6	−	+		−	−			−	−			−			−	−	−		−	−
ER-7	−	+		−					−			−			−	−	−		−	−
ER-8	−	+											+		−	−	−			−
ER-9	+	+		−		+	−			−					−	−	−	−		
ER-10	−	+	−												−	−	−			

(■ = box shaded, no sign legible)

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SEATTLE, WA. ANCHORAGE, AK.

AREA ASSESSMENT MATRIX

SAND LAKE

ANCHORAGE NATURAL RESOURCES (GRAVEL) EXTRACTION MANAGEMENT STUDY

IMPACTS / BENEFITS ASSESSMENT

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- 1.6 INDUSTRIAL - ENHANCE/IMPACT

LAND USE, FUTURE
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NATURAL RESOURCE / EXTRACTION SITES

SITE NO.	DESCRIPTION SUMMARY
SL-1	MIL PIT - 40 ACRES, LOCATED ON NORTHSIDE OF KINCAID ROAD APPROXIMATELY ONE-HALF MILE WEST OF SAND LAKE ROAD. OWNER PLANS TO DEVELOP PROPERTY FOR OTHER THAN NATURAL RESOURCE EXTRACTION. DORMANT.
SL-2	SAND LAKE AGGREGATE - 60 ACRES, LOCATED ON SOUTH SIDE OF KINCAID ROAD, APPROXIMATELY 1,500 FEET WEST OF SAND LAKE ROAD. OWNER PLANS TO DEVELOP PROPERTY FOR OTHER THAN NATURAL RESOURCE EXTRACTION. ACTIVE.
SL-3	IRVIN EVENSON/ANCHORAGE SAND AND GRAVEL - 80 ACRES, LOCATED ADJACENT TO AND SOUTH OF KINCAID ROAD, AND ADJACENT TO AND WEST OF SAND LAKE ROAD. NORTH 10 ACRES OF THIS PROPERTY HAS NOT BEEN MINED. ACTIVE.
SL-4	SKY HILLS - 60 ACRES, LIES SOUTH OF EVANSON COURT AND WEST OF LUCY STREET. OWNER PLANS TO DEVELOP PROPERTY FOR OTHER THAN NATURAL RESOURCE EXTRACTION. DORMANT.
SL-5	SUSKY PIT/ANCHORAGE SAND AND GRAVEL - 20 ACRES, LOCATED EAST OF LUCY STREET EXTENDED, DORMANT; TO BE RESTORED AND DEVELOPED AS R - 1A. RESOURCE DEPLETED.
SL-6	SEAVIEW PIT - 56 ACRES LOCATED 660 FEET NORTH OF W. DIMOND BOULEVARD. ACTIVE.
SL-7	HAROLD WRIGHT PIT/ROGERS AND BABLER - 40 ACRES, LOCATED WEST OF AND ADJACENT TO SAND LAKE ROAD. TO BE RESTORED AND DEVELOPED AS R - 1A. ACTIVE.
SL-8	ANCHORAGE SAND AND GRAVEL - 40 ACRES LOCATED EAST OF SAND LAKE ROAD AND SOUTH OF W. 84 AVENUE. RESOURCE DEPLETED. TO BE RESTORED AND SOLD. DORMANT.
SL-9	STEPHAN AND SONS - 30 ACRES, LOCATED WEST OF SAND LAKE ROAD AND NORTH OF WEST DIMOND BOULEVARD. ACTIVE.
SL-10	RCJ PIT - 40 ACRES, LOCATED AT THE NORTHEAST CORNER OF W. DIMOND BOULEVARD AND SAND LAKE ROAD. ACTIVE.
SL-11	ALICE TALLMAN - 10 ACRES, LOCATED AT THE NORTHWEST CORNER OF W. DIMOND BOULEVARD AND SNEAD ROAD. THIS IS A PROPOSED PIT.

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